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FMC CORPORATION (A)

Need For a Rice Sorter

Shortly after his appointment as Director of the Electronics Section of the Product Development Department of FMC Corporation's Central Engineering Laboratories, Dr. T. E. Roberts organized a technical group to study problems of quality sorting using electronics. One application considered was in the area of rice sorting. The objective in this area was to remove dark grains which typically constituted 5% by weight of rice processed for retail sale or use in soups and other food products. A market study by FMC indicated that if a machine would be developed to separate at an input rate of 2,000 pounds per hour, FMC could sell from 15 to 45 sorters. Dr. Roberts stated, "We think that there is a sure market in rice, and if we perfect a method for mechanizing rice sorting, we may find other applications for it as well."

Prepared in the Design Division of the Mechanical Engineering Department by J. Kendall Williams under the direction of Karl H. Vesper. The assistance of Dr. T. E. Roberts, Jr., and Arthur Slemmons of the Central Engineering Laboratories, and John Boyce, S. H. Creed, and Don Chamberlin of the Canning Machinery Division is gratefully acknowledged. Financial support for this study was provided by the National Science Foundation.

FMC Corporation

FMC was continually seeking new products suited to its production and sales capabilities. It tried to avoid direct competition with electronics companies, although it favored the application of electronics in new products. Dr. Roberts noted, "If the Central Engineering Laboratories built a strictly mechanical machine to size a peach, for example, there are a lot of small shops with overhead much less than ours to compete with. Maybe they should be doing that business, and we should be doing something that requires additional engineering."

The history of FMC Corporation dates back to the 1880's, when two separate events occurred at opposite ends of the United States. In the Santa Clara Valley of northern California, a young inventor named John Bean developed a new orchard sprayer and founded a small company to produce spray pumps for neighboring fruit growers. In New Jersey, Dr. Lucian Warner founded a chemical company to produce sodium phosphates and related products. In 1929, the John Bean Company changed its name to Food Machinery Corporation after purchasing an eastern canning machinery firm. In 1948, Food Machinery Corporation acquired Westvaco Chemical Corporation, a direct outgrowth of Dr. Warner's chemical venture. The parent company became Food Machinery and Chemical Corporation. In 1961, the name was changed to FMC Corporation.

FMC expanded its product line to include outdoor power equipment, food service equipment, crop harvesters, petroleum production hardware, fruit and vegetable packing and processing equipment, packaging equipment, pumps and water systems, military personnel and weapons transporters, and diversified chemical products for agricultre and industry. A more detailed listing of the company's products appears in Exhibit 1.

By 1963, FMC's operations included 15 manufacturing divisions and six subsidiary operations, including 64 production units throughout the United States, Canada, and Mexico. Overseas plants were located in England, Belgium, France, Spain, South Africa, Australia, and Brazil. In 1963, the Corporation employed approximately 33,000 people. The corporation's gross income from sales and other operating revenue for 1963 was approximately $617 million.

The Central Engineering Laboratories

The Central Engineering Laboratories were organized in 1946 to generate new products and perform research for product innovation and improvement. CEL[1] began in 1946 with approximately 35 engineers, most of whom had advanced degrees. By 1963, it employed 387 people, including 133 engineers with B.S. degrees, 35 with M.S. degrees, and 4 with Ph.D. degrees.

(1) CEL is the abbreviation for Central Engineering Laboratories

CEL was divided into the "FMC Machinery/Systems Group", primarily concerned with work for the U.S. Government and industry, and the "Research and Development Branch", primarily concerned with the development of FMC proprietary products. The Machinery/Systems Group was further divided into the Program Development Department, Project Operations Department, Systems Engineering Department, and Equipment Engineering Department. The Research and Development Branch consisted of the Product Development Department, Process Development Department, and the Materials Laboratory. CEL facilities included two machine shops and several experimental and testing laboratories. The organization of CEL is diagrammed in Exhibit 2.

The Product Development Department employed 50 engineers organized in separate sections including Electronics, Mechanical, Packaging, Weighing Equipment, and Engineering Design sections. Facilities of the department included an electronics laboratory and several testing laboratories.

Prior to 1957, CEL developments were of a primarily mechanical nature. Successful products included an orange juicer capable of squeezing sets of eight oranges at a rate of one set/second. The design provided for piercing and squeezing of the whole orange without getting skin oil in the juice or damaging the skin, which was used later in an oil reclaiming process. Also developed was a high speed "check-weigher" capable of weighing 200 to 300 articles per minute, each article weighing from several ounces to several pounds. CEL designed several models of this electromechanical weigher.

CEL served as a consulting organization for other FMC divisions. Funds for research and development were provided by each division that requested services and by the central office of the corporation. All research was aimed at applications of known practical importance, but some research was done independent of specific division support. CEL was often concerned with 100 projects at one time. Several small projects were frequently handled by a single engineer, while a large project required five or six engineers, generally organized under a project engineer.

Projects were often selected on the basis of market research performed by CEL personnel. Investigation of rice sorting was done as part of the "Engineering Analysis" step of a ten step program used in all FMC development projects. A "Development Project Work Sheet", which described each step of the program, was used by FMC engineers to plan projects. Dr. Roberts noted, "The estimates from the work sheets are very helpful in economic planning, but engineers generally don't like to fill them out. The work sheet calls for detailed figures, while costs for phases of a research and development project can only be rough estimates."

Each engineer was required to estimate the labor, burden (overhead), material charges, total cost, and completion date for his part of a project prior to initiation of his work. He also accounted for money spent and appropriated and submitted requests for additional funds to the project engineer or department supervisor. In 1957, CEL engineers estimated direct labor costs at a rate of $3.00 per hour, design costs at

$4.00 per hour for an engineer or $5.00 per hour for a senior engineer, and burden at 2 times each figure respectively.

The progress of a project was generally reviewed after the first two steps were completed and after the fifth step, when responsibility for carrying out steps 6 through 10 was frequently transferred to another division of the corporation. The ten-step program is described in greater detail in Exhibit 3.

Dr. Roberts, Manager of the Product Development Department, received a B.S. degree in electrical engineering in 1943 from Georgia Tech. After graduation, he began a 3-1/2 year tour of service with the Army Signal Corps, as a radar officer. At the end of the war, he taught electronics in Germany. In 1947, Dr. Roberts returned to Georgia Tech to teach. His career ambition at that time was to be a teacher. In 1951, he became an Associate Professor of Electrical Engineering at Georgia Tech after completing 3-1/2 years of graduate study at Harvard University.

In 1952, Dr. Roberts' career plans changed. He commented, "I was very eager to apply the theory that I had learned in school, and I found teaching too restrictive in this respect." He moved to Connecticut to work for United Aircraft Corporation's Norden Division, which had manufactured the Norden bombsight during World War Two. When the advanced development group that Dr. Roberts had anticipated failed to materialize at Norden, he accepted a position with the American Machine and Foundry Company in Connecticut where he worked on the development of radar antennas and low frequency, high powered radar. Dr. Roberts was transferred in 1956 to AMF's Raleigh Engineering Laboratory in Raleigh, North Carolina, as Laboratory Technical Director. Dr. Roberts began his work for FMC's Central Engineering Laboratories in 1957.

Par-Boiled Rice

CEL had designed quality control and sorting equipment of a primarily mechanical nature prior to 1957. Feeling that electronics could also have sorting applications, Dr. Roberts asked an application engineer to visit food processors and determine where an electronic sorting machine would be used. Processors of wheat, beans, coffee, diced carrots, apples, lemons, peaches, and tomatoes were contacted in this investigation. The study concluded that the largest potential sales lay in sorters for "par-boiled" rice.

Rice is generally processed as par-boiled or white rice. Par-boiled rice is high quality rough rice which has been steam cooked prior to removal of hull and bran[1] from grain. Steam cooking causes vitamins and water soluble nutrients in bran to be absorbed by the grain and also

(1) Bran is the waxy layer between the hull and grain.

increases the grain's structural strength and resistance to spoilage. Because this process increases cost, not all rice is par-boiled.

Use of par-boiled rice became important during World War II when the U.S. Army used large quantities. Some major canning companies use only par-boiled rice in soups because it can better withstand high cooking temperatures needed to kill bacteria.

Dark Grains

One of the principal defects in rice is caused by insect bites on immature grain. The insect bites cause black areas called "peck" to appear on the grains. The bite also stunts growth of the kernel, resulting in a slightly smaller than usual grain. "Pecky" rice is unacceptable on the American market; however, it is combined with good rice and sold to countries of the Middle East like India where the defect is not considered objectionable. Samples of typical good and pecky grains are pictured in Exhibit 4.

CEL had not collected data on all physical properties of rice grains. Some data had been compiled on optical properties, including the spectrophotometer curves noted in Exhibit 5. Par-boiling changes the color of normally white grain to a yellow or amber and the color of defects from purplish brown to reddish-brown or black. Typical rice grains measure approximately 1/4 inch long by 1/16 inch in diameter. On the average, pecky grains are slightly smaller than good grains. Depending on the variety of rice, the grain count varies from 25,000 to 35,000 grains per pound. A retailed package of rice weighing one pound typically measures 1 1/4" x 4" x 7".

In rice that is not par-boiled, pecky grains are structurally weaker than good grains. Defective rice is normally broken in the milling process and separated mechanically by sifters. Par-boiling increases the strength of these grains to the point where they cannot be selectively broken by milling and easily sorted. Prior to World War II, hand methods were usually used for sorting. Dr. Roberts noted that as many as 200 girls per shift were employed by some plants to sort rice with vacuum hoses. Because of high costs, most hand sorting operations were discontinued, and a lower quality product resulted.

Rice Processing

In 1959, par-boiled rice was produced by four mills in the United States: the Valley Rice Association[1] in Sacramento, California, and the Star Rice Mills,[1] Longhorn Rice Mills,[1] and Consolidated Rice Company,[1] in Houston, Texas. The mill in Sacramento processed a short grain rice, whereas the Texas mills processed a long grain variety.[2] Peck appeared in both types.

(1) Names fictitious
(2) "Market Analysis for a Grain Separator," P.W. Lampman, FMC Corporation, 1959.

The Star Rice Mills handled approximately 10,000 tons of par-boiled rice and 45,000 tons of white rice per year. Their par-boiled plant operated at 80 to 100 cwt[1] per hour, and the white rice plant operated at approximately 175 cwt per hour. Pre-selected rough rice with 4-5% peck was cleaned of hay and seed in an aspirator operated by blowing air through a flowing sheet of rice. The rice was then par-boiled in a steam cooker, dried and transferred by a conveyor to the milling stone. Rice conveyors were either screw feeds or gravity fall tubes. The milling stone consisted of two concrete and carborundum composition disks of 60 inches in diameter. Rice was fed through the central support shaft of the upper disk which rotated relative to the fixed lower disk. Rice was moved by the rotation of the upper disk to the outer periphery of the stone. The gap between the disks was adjusted so that the hulls were cracked free without crushing grains. Milled rice was collected in a conical hopper beneath the stone and conveyed to the second aspirator which removed loose hulls.

The milling operation generally did not mill all grains due to size differences between grains. A paddy separator sorted milled and unmilled grains on the basis of weight difference. Rice was poured on the center of a slanting shaker table measuring five feet wide by 12 feet long. One long edge was 12 inches higher than the other. Corrugated channels traversed the width of the table. Heavy unmilled rice was sifted to the bottom of the stream at the center of the table, gradually moved to the lower edge by incoming rice, and fed into a conveyor which returned the rice to the stone. Lighter milled rice moved to the upper edge and was transferred to a scraper for bran removal.

The scraper consisted of a horizontal cylinder, six feet long and two feet in diameter, which rotated inside a cylindrical wire screen. Spiral ridges on the cylinder moved the rice axially while the screen scraped bran off the grains. Rice was then transferred to the third aspirator which removed loose bran. Bran not removed by the scraper was removed in the brush, which consisted of a vertical leather padded cylinder which also rotated inside a cylindrical wire screen. The resilient padding allowed greater freedom of movement of grains relative to the screen, and consequently, the ends as well as the sides of the grains were cleaned.

Broken rice, which constituted 10% to 30% of the total input, was separated from whole rice in two operations. Brewer's rice or 1/3 length kernels were sorted by a sizing screen or sieve. Second-heads (3/4 to 1/2 length kernels) and screenings (1/2 to 1/3 length kernels) were removed by a set of 30 Carter Disks mounted on a common horizontal shaft. Stamped indentations in the one foot diameter disks picked broken grains out of the trough in which the disks were turning.

Whole rice from the Carter disks were sorted mechanically into three grades by two sets of precision graders. Each precision grader had six tilted revolving drums with small slots arranged in a spiral path around the cylinders. Rice which passed completely through the first precision graders was called 1st Fancy. It contained 0.7% to 1.0% peck and consti-

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(1) A weight equal to 100 pounds.

tuted 60% to 80% of the whole kernels. Rice which passed through the slots, containing from 6% to 21% peck, was conveyed to a second set of graders which sorted the remaining stream into 2nd Fancy grade (10% to 30% of the whole kernels) and 3rd Fancy grade (10% of the whole kernels). The rice processing line of the Comet Mills is diagrammed in Exhibit 6.

Mr. P. W. Lampman noted in his market analysis[1] that a rice sorting machine could be used on such a line to eliminate completely the precision graders. He stated, "...if all but 1% of the peck could be removed from the entire stream, the sorted rice could all be sold as 1st Fancy." Typical rice prices and U.S.D.A. grade specifications for milled rice are noted in Exhibit 7.

(1) Op. Cit., P. W. Lampman.

Exhibit 1. FMC Products

American Vixcose Division
Philadephia, Pennsylvania
Principal Products: rayon, filament, tire yarn, cellophane, plastics.

Bolens Division
Port Washington, Wisconsin
Principal products: riding lawn and garden tractors, rotary tillers, lawn mowers, snow casters.

Canning Machinery Division
San Jose, California
Principal Products: equipment for food preparation and processing, kitchen service equipment, and frozen stick confection equipment.

Fairfield Chemicals
New York, New York
Principal Products: Basic materials for formulators of pesticides.

Florida Division
Lakeland, Florida
Principal Products: Deciduous fruit, citrus, and vegetable packing and canning equipment, concrete casting forms, industrial castings.

Hydrodynamics Division
Peerless Pump
Los Angeles, California
Principal Products: Horizontal and vertical pumps, water systems, nuclear liquid pumps.

Chicago Pump
Chicago, Illinois
Principal Products: Sewage and waste treatment equipment, building trades and sewage pumps.

Coffin Turbo Pump
Englewood, New Jersey
Principal Products: Turbo pumps.

Mechanical Foundries
Los Angeles, California
Principal Products: Aluminum, brass, bronze, grey iron, and magnesium foundry castings.

Sonith Foundries
Indianapolis, Indiana
Principal Products: Meehanite, brass, and bronze castings.

Inorganic Chemicals Division
New York, New York
Principal Products: alkalis, ammonia, barium chemicals, carbon tetra-chloride, caustic soda, hydrogen peroxide, leavening agents, peracetic acid, perozygen chemical specialties, phosphorus chemicals, soda ash, sodium phosphates.

John Bean Division
Lansing, Michigan
Principal Products: Automotive wheel aligners and balancers, brake repair tools, industrial sprayers and dusters, potato harvesters, fire fighting equipment.

John Bean Division - Western Operation
San Jose, California
Principal Products: Airline service equipment, industrial sprayers, potato harvesters, fire fighting equipment.

Niagra Chemical Division
Middleport, New York
Principal Products: Agricultural chemicals and insecticides.

Oakes Manufacturing Company
Tipton, Indiana
Principal Products: pultry and hog equipment, egg graders, power sprayers.

Ordinance Division
San Jose, California
Principal Products: Military tracked and wheeled vehicles, amphibious landing and hydrofoil vehicles, nuclear handling equipment, missle and aerospace ground support systems and equipment

Organic Chemicals Division
New York, New York
Principal Products: Allylic resins and monomers, Dapn resins and sealants, plasticizers, chlorides, epoxy resins and epoxy chemicals.

Packaging Machinery Division
Stokes and Smith Plant
Philadelphia, Pennsylvania
Principal Products: Filling and packaging machinery, box machinery, checking weighers.

Kingsbury and Davis Plant
Contoocook, New Hampshire
Principal Products: Quadruple staying machines for paper box industry.

Hudson-Sharp Plant
Green Bay, Wisconsin
Principal Products: Paper and film converting equipment, wrapping machinery, printing presses.

Simplex Plant
Oakland, California
Principal Products: Bag making machines, filling and sealing machines, tying machines.

Packing Equipment Division
Riverside, California
Principal Products: Automatic egg grading and packing equipment, nailing equipment, truck and trailer bodies, fruit and vegetable packing house equipment, protective processes.

Petroleum Equipment Group
Chiksan Division
Brea, California
Principal Products: Swivel joints and assemblies for tank, truck and barge loading.

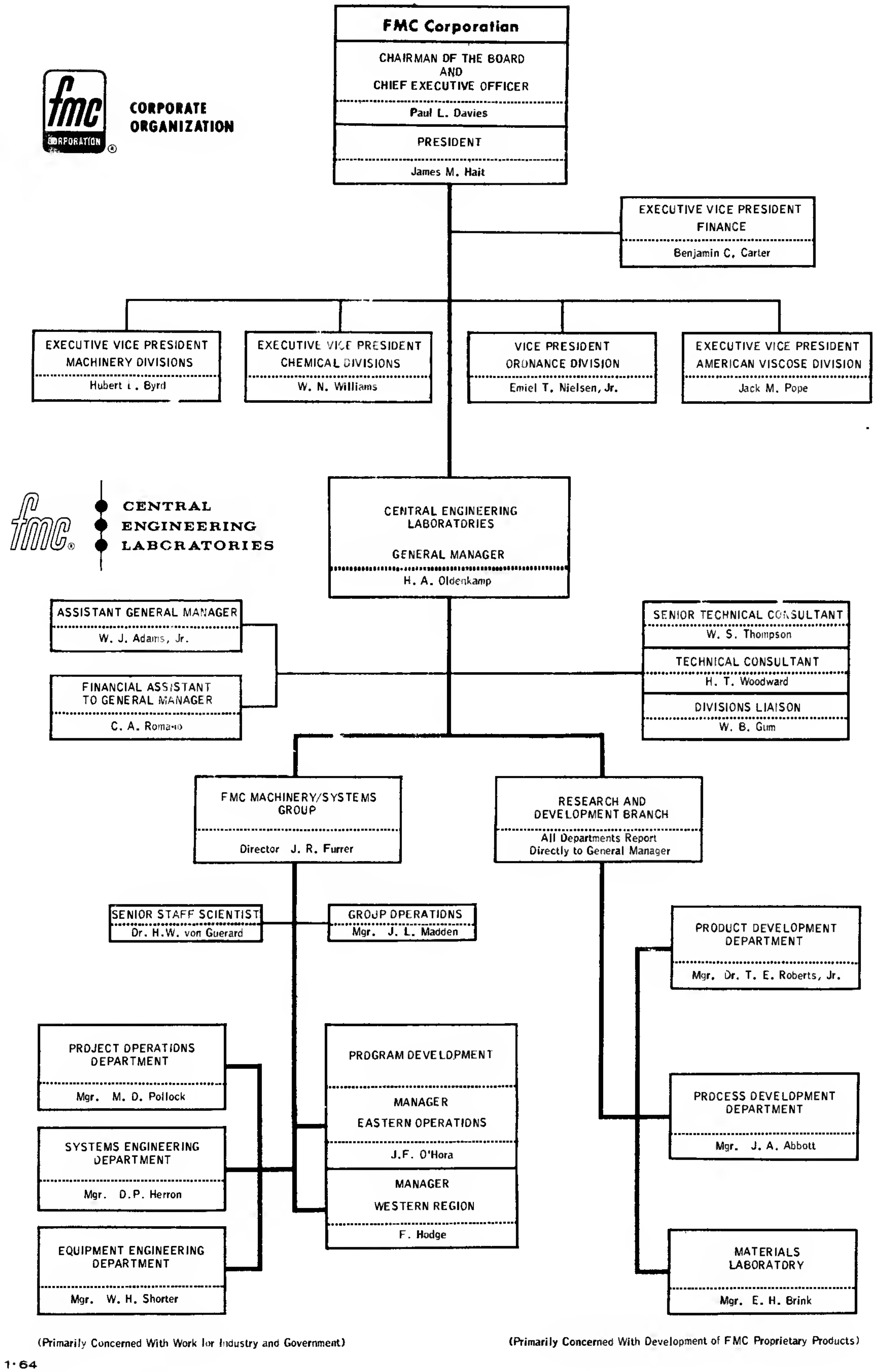
Oil Center Tool Division
Houston, Texas
Principal Products: Wellhead equipment, gate valves, underwater completion equipment.

Weco Division
Houston, Texas
Principal Products: Speciality oilfield equipment.

FMC International
Machinery Export Headquarters
San Jose, California
Chemical Export Headquarters
New York, New York
Principal Products: Export sales of machinery products, chemicals, food processing and packaging machinery lines, overseas installation of complete food processing, paper converting, and packaging plants.

Central Engineering Laboratories
Headquarters Operation
Santa Clara, California
Principal Products: Specialized machinery and equipment including fabrication, assembly, filling, sorting, handling, digital control, and process equipment; systems analysis to introduce efficiency in production operations.

Exhibit 2. Corporate Organization



Courtesy of FMC Corporation.

Exhibit 3. Development Project Work Sheet.

Form CRD-2

Division________________ Date________________ Div. Project No. ________
FMC Project No. ________

DEVELOPMENT PROJECT WORK SHEET

Original________
Revision No. ________
To Close ________

Title________________________________

STEP	SUB STEPS	MAN MO.	LABOR	BURDEN	MATERIAL & OUTSIDE CHARGES	EST. TOTAL COST	SPENT TO DATE	APPROP. TO DATE	APPROP. TO BE REQ'BTED	EST. COMPL. DATE
1	**Engineering Analysis** 1. Evaluation of requirements. 1.1 Consultation with Sales & Merketing. 1.2 Consultation with potential customers. 2. Prior Technical Art 2.1 Patents. 2.2 Competition. 3. Conception and evaluation of alternative schemes. 4. Estimate of time and cost for all steps and special tooling. 5. Estimate of Manutacturing Cost. 6. Possible Financial Return. 7. Preperation of report to include: 7.1 Analysis of critical technical elements. 7.2 Parformance requirements. 7.3 Preliminary Dasign Specitications. 7.4 Datailed recommandations including appropriation request for subsequent steps if nacessary.		Objectives: Supported By:				Work Performed By:			
	Total for Step 1									
2	**Development Exploration** 1. Thorough study of alternativas. 1.1 Calculations. 1.2 Study lay-outs & schematics. 1.3 Conclusions. 2. Jury Rig tests of untriad principlas. 3. Further check of patents. 4. Consultations with unbiased tachnical sources. 5. Consultation with Manufacturing and salas. 6. Preparation ot raport to include: 6.1 Summary of test rasults. 6.2 Evaluation of potantial technical success 6.3 Manutacturing feasibility of schama chosan. 6.4 Reviaw ot Sales Department comments. 6.5 Revlsed astimate ot total steps cost. 6.6 Revlsad estimate of Manufacturing Cost. 6.7 Recommandations and appropriation requast for turther work, if necessary.		Objectives: Supported By:				Work Performed By:			
	Total for Step 2									
3	**Development Model Design** 1. Preparation ot layouts. 2. Re-check with Manufacturing & Sales. 3. Consultation with outside specialists. 4. Preparation ot detail drawings. 5. Re-check patents. 6. Issue drawings tor Development Model construction. 7. Preparation ot Report to include: 7.1 Evaluation ot progress to date. 7.2 Re-evaluation of all costs. 7.3 Discussion ot necessary compromises. 7.4 Recommendations tor changes to specifications. 7.5 Recommendations tor tuture action end new appropriation request, it necessary.		Objectives: Supported By:				Work Performed By:			
	Total for Step 3									
4	**Development Model Construction** 1. Purchase materials. 2. Methodize. 3. Manutacture & Shop Test. 4. Moditications. 5. Engineering Liaison with Shop. 6. Preparation ot report to include: 6.1 Manutacturing teasibility. 6.2 Recommendations tor moditications to aase manutacturing problems. 6.3 Review ot manutacturing costs and projects cost to date versus estimate. 6.4 Recommendations tor future action and new appropriation request, it necessary.		Objectives: Supported By:				Work Performed By:			
	Total for Step 4									

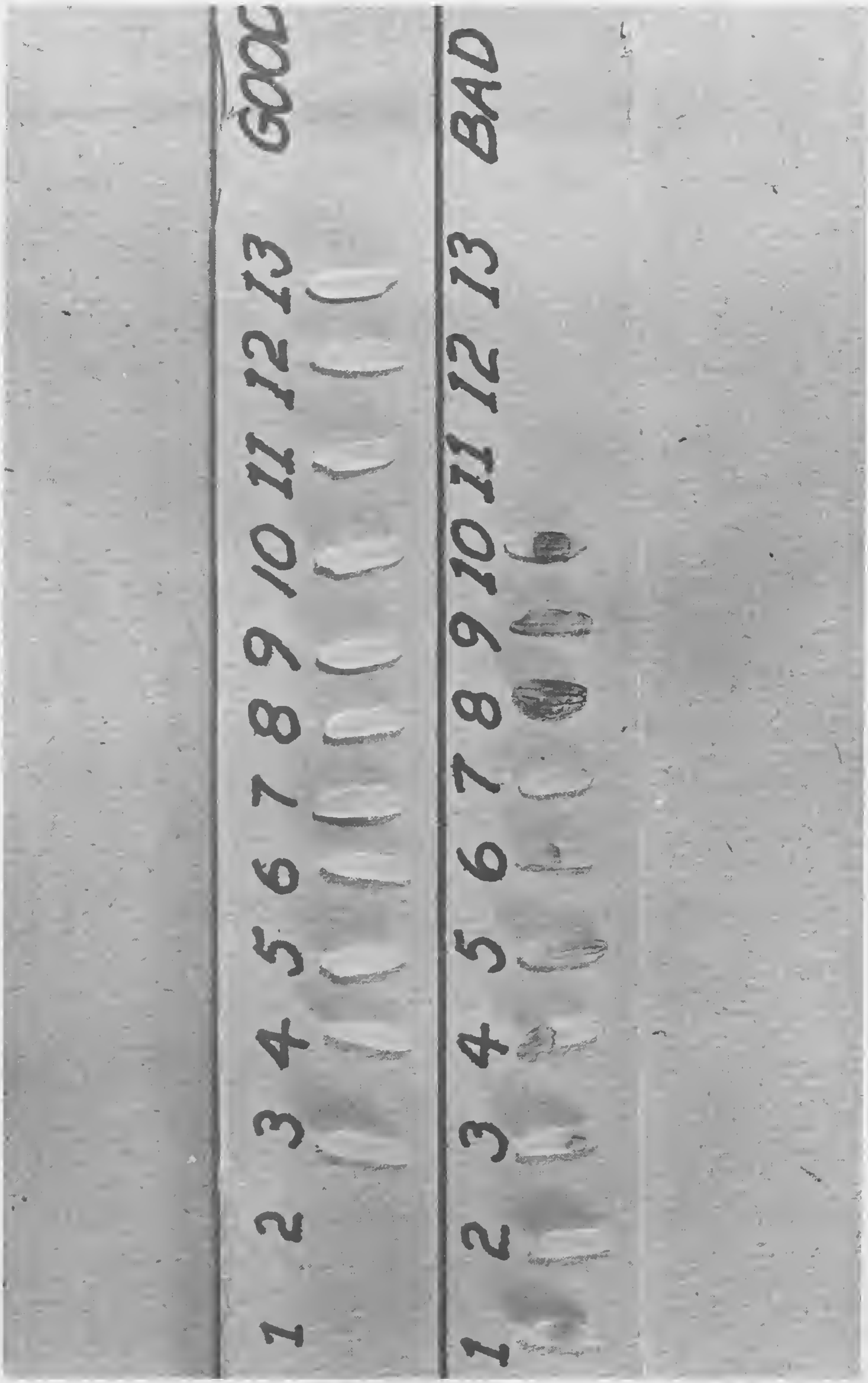
Courtesy of FMC Corporation

Exhibit 3. Development Project Work Sheet.

STEP	SUB STEPS	MAN MO.	LABOR	BURDEN	MATERIAL & OUTSIDE CHARGES	EST. TOTAL COST	SPENT TO DATE	APPROP. TO DATE	APPROP. TO BE REQ'STED	EST. COMPL. DATE
5	**Development Model Test** 1. Establish test specifications compatible with performance requirements. 2. Installation and operation of model. 3. Installation of instrumentation. 4. Evaluation of test data. 5. Sales Department opinion. 6. Preparation of report to include: 6.1 Comparison of test data with specifications. 6.2 Recommended design changes. 6.3 Revised specifications (if necessary) for production models. 6.4 Re-evaluation of all costs, comparing with estimates. 6.5 Recommendations for future action and new appropriation request, if necessary.		Objectives: Supported By:			Work Performed By:				
	Total for Step 5									
6	**Production Model Design** 1. Consultation with development engineers. 2. Consultation with outside specialists. 3. Re-affirmation that device which has been developed to date will meet specifications. 4. Preparation of layouts, details, assemblies, bills of material. 5. Set up liaison with development engineer for his confirmation that final drawings will meet performance specifications. 6. Re-check patents. 7. Cost reduction studies. 8. Manufacturing & Tooling cost estimates. 9. Re-check with Marketing and Sales. 10. Preparation of report to include: 10.1 Discussion of how well design will meet specifications. 10.2 Prediction of manufacturing difficulties. 10.3 Recommendation for areas of future cost reduction effort and/or changes to improve saleability. 10.4 Other recommendations for future action including appropriation request, if necessary.		Objectives: Supported By:			Work Performed By:				
	Total for Step 6									
7	**Production Model Construction** 1. Temporary tool design and manufacture. (If production type required apply to step 10.) 2. Purchase materials. 3. Methodize. 4. Manufacture & Shop Test. 5. Modifications. 6. Engineering liaison. 7. Preparation of report to include: 7.1 Actual manufacturing and tooling costs compared to estimates. 7.2 Evaluation of manufacturing problems. 7.3 Recommendations for improvement.		Objectives: Supported By:			Work Performed By:				
	Total for Step 7									
8	**Production Model Test** 1. Establish test procedure to be compatible with performance requirements. 2. Check with development engineer who tested previous model for common problems. 3. Installation and operation. 4. Evaluation of test data. 5. Impartial evaluation preferably by competent technical men not connected with organization. 6. Customer reaction—Sales Department? 7. Preparation of report to include: 7.1 Comparison of test results with performance specifications. 7.2 Recommended modifications for first production lot. 7.3 Recommended final inspections. 7.4 Review of economics. 7.5 Recommendations for future action and appropriation request, if necessary.		Objectives: Supported By:			Work Performed By:				
	Total for Step 8									
9	**Final Engineering Drawing** 1. Finalize drawings and bills of material. 2. Special engineering-manufacturing instructions. 3. Preparation of data for installing, operating and servicing. 4. Training service personnel. 5. Release of drawing. 6. Preparation of final report to include: 6.1 Review of all costs compared to estimates. 6.2 Final review of economics with current prediction for sales obtained from Sales Department. 6.3 Review of engineering performance, noting areas which should be improved. 6.4 Further recommendations.		Objectives: Supported By:			Work Performed By:				
	Total for Step 9									
10	**Special Tooling** 1. Final special tooling design and manufacture. 2. Modifications to special tool found necessary in first run.		Supported By:			Work Performed By:				
	Total for Step 10									
	Total for All Steps									

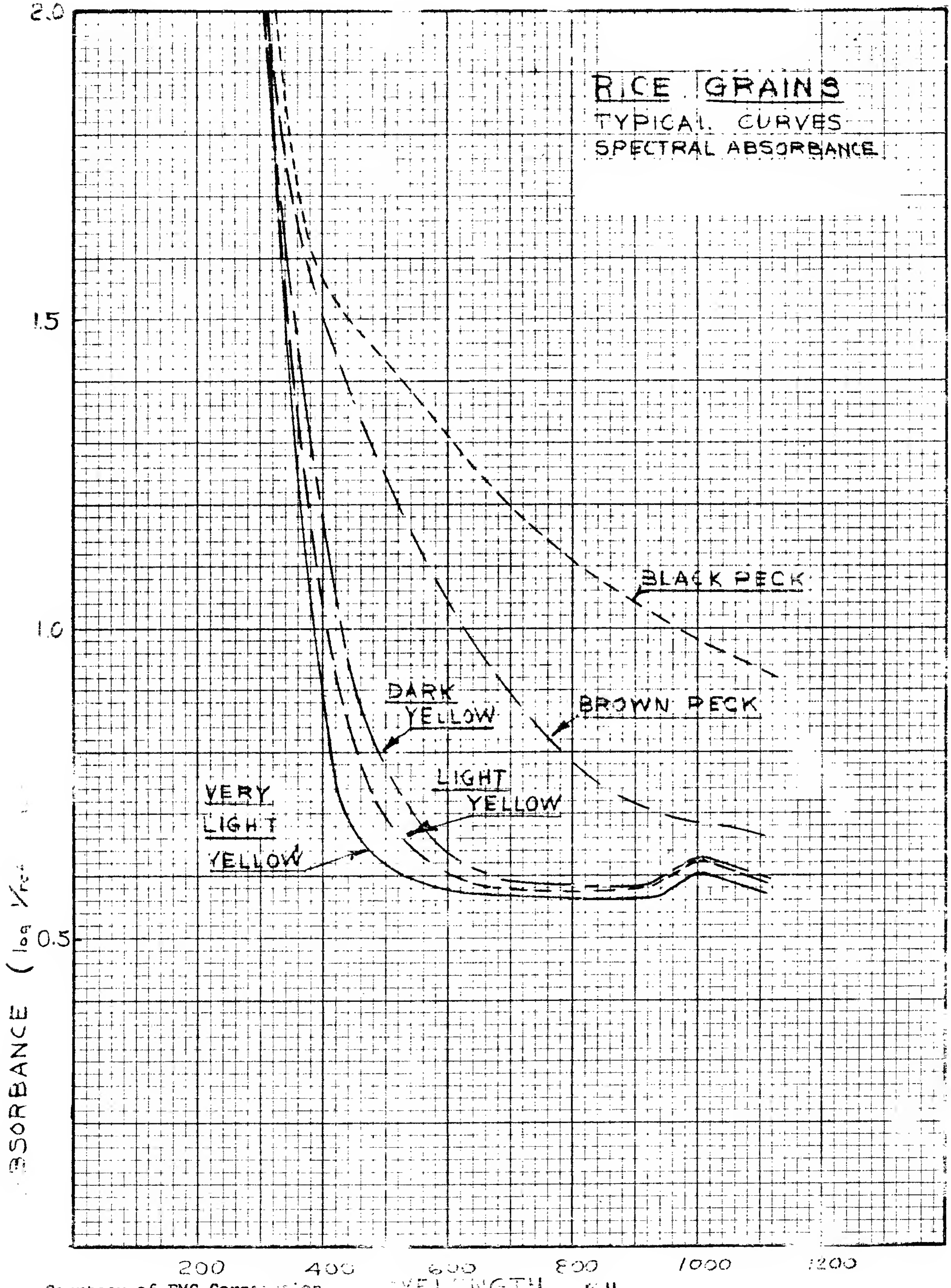
Courtesy of FMC Corporation

Exhibit 4. Rice Grains.



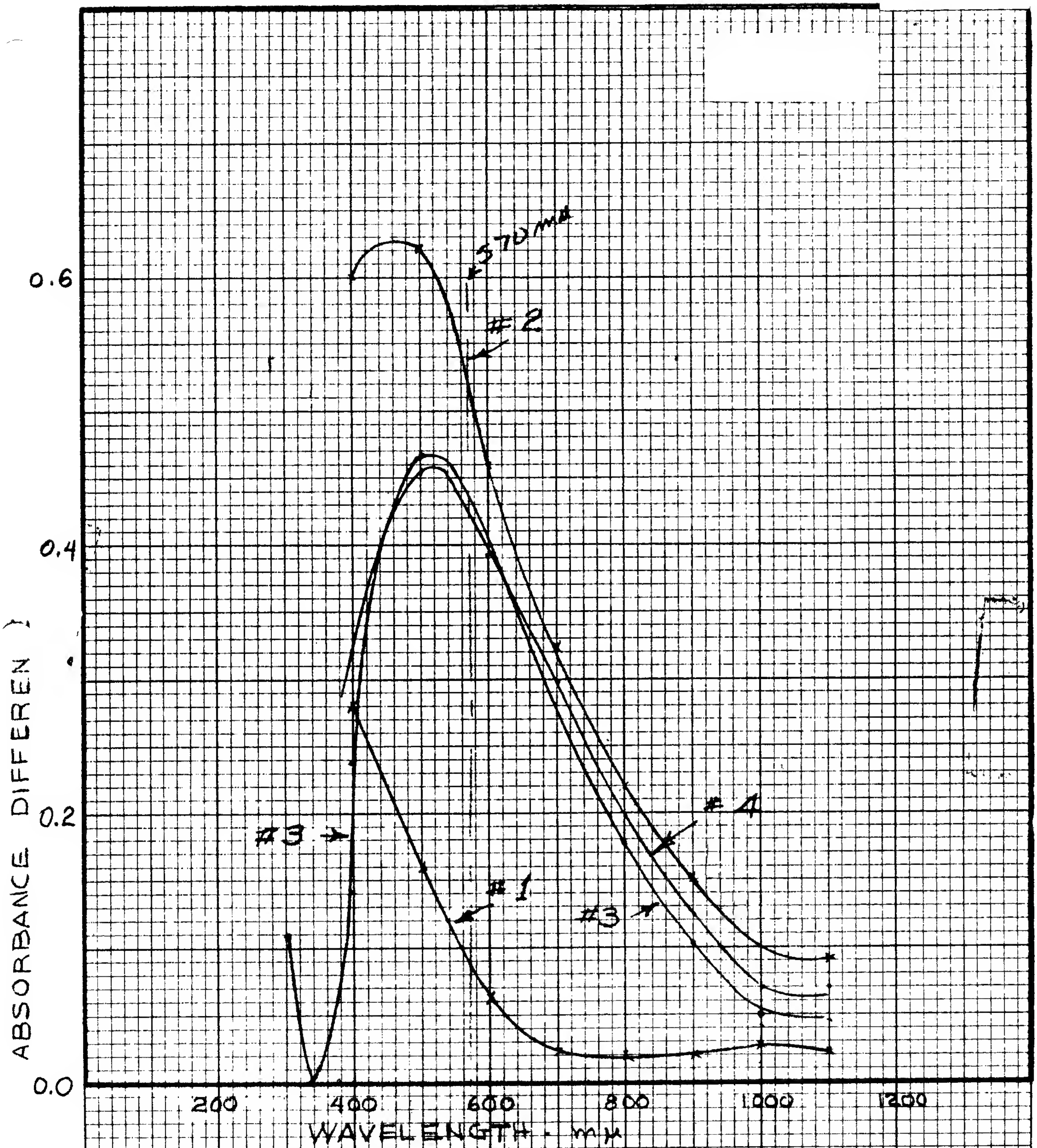
Courtesy of FMC Corporation

Exhibit 5. Rice Spectral Absorbance



Courtesy of FMC Corporation

Exhibit 5. Rice Spectral Absorbance



Absorbance differences for good and bad rice grains. (Ref. Figure 2)

1. Difference between very light and dark yellow grains.
2. Difference between very light yellow grain and brown peck.
3. Difference measured by spectrophotometer using a small cup of good rice as reference and pecky rice as sample.
4. Difference between dark yellow grain and brown peck. Curves 1, 2, and 4 obtained by calculation from date of Figure 2.

Exhibit 6. Par-Boiled Rice Processing

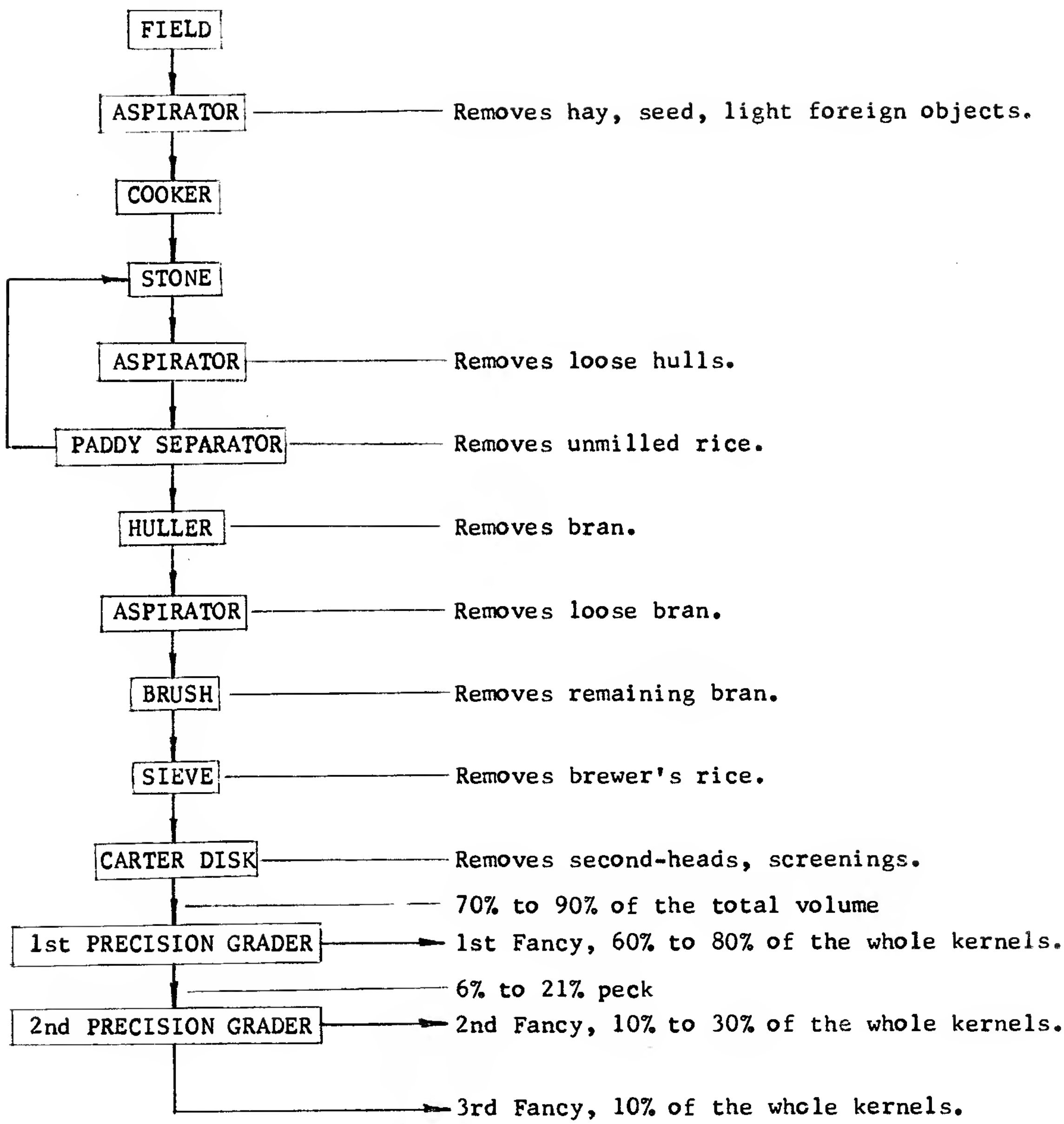
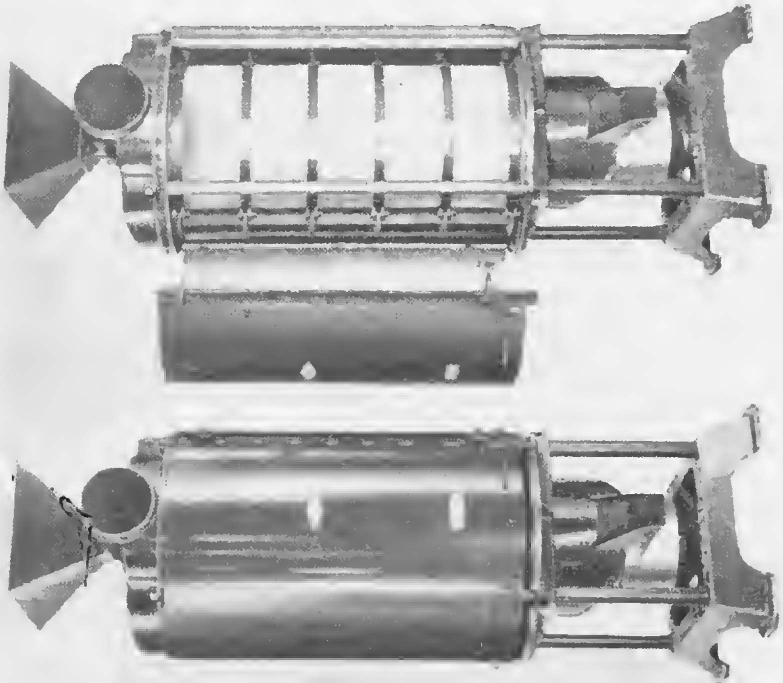


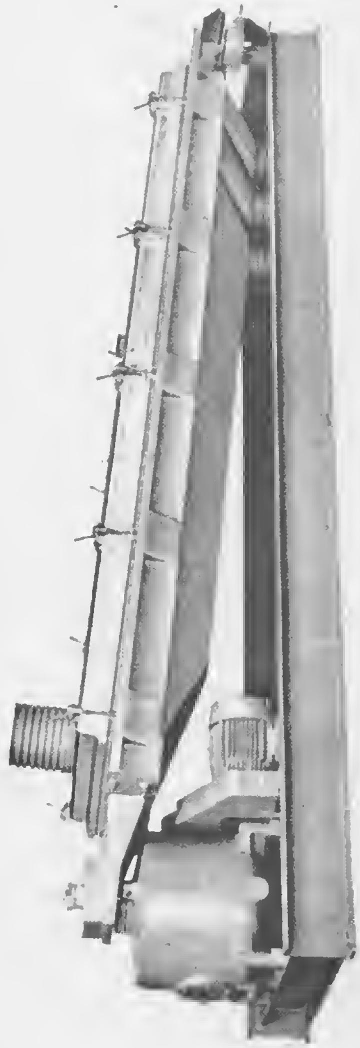
Exhibit 6. Par-Boiled Rice Processing.

Note: Cost figures vary with machine capacity.



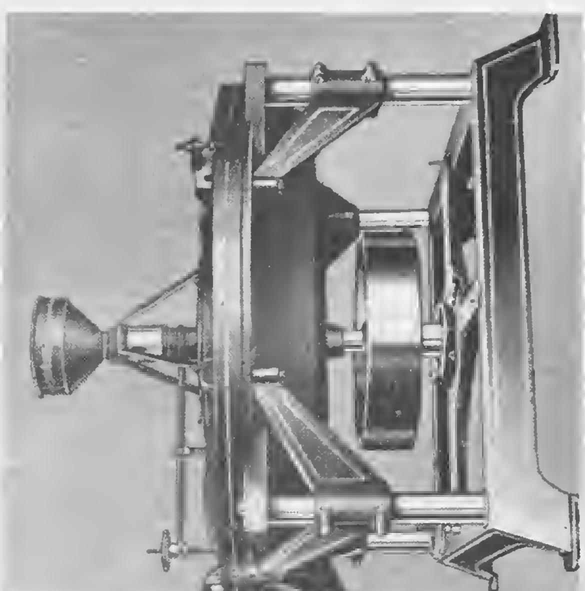
8'

Brush: $ 3,000 - $ 5,200



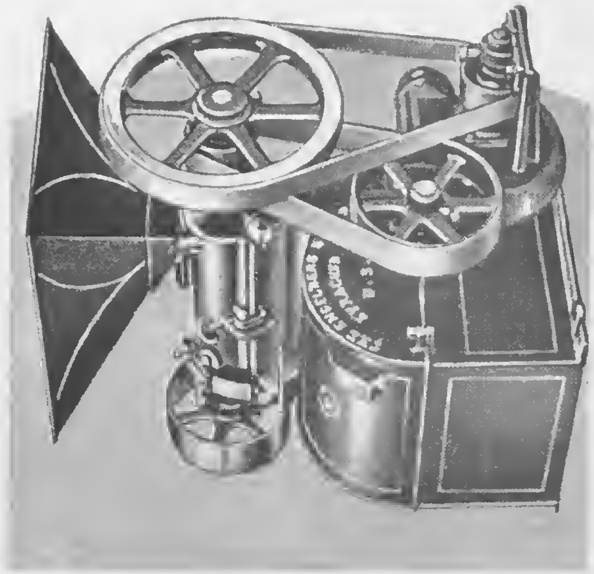
12'

Sieve: $ 750 - $ 4,000



5'

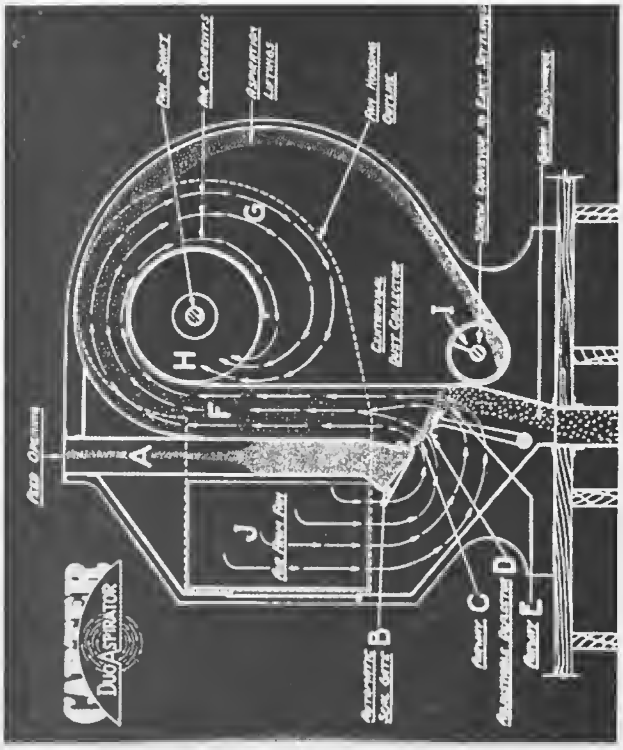
Stone: $ 1,200 - $ 3,400



4'

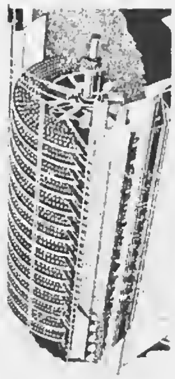
Scraper: $ 1,400 - $ 1,500

Note: Cost figures vary with machine capacity.



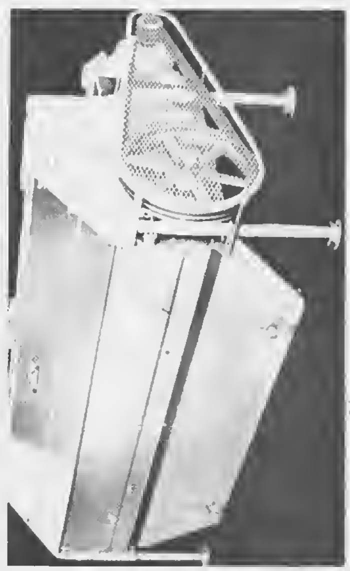
Aspirator: $ 2,000 - $ 12,000

Paddy Separator: $ 2,500 - $ 13,000



Disk Operation

Disk Detail



Carter Disk: $ 900 - $ 5,200

Precision Grader: $ 3,000 - $ 3,200

Exhibit 7. Rice Prices.

Rice	Per Cwt
Long grain head rice	\$9.00 - \$10.00
Long grain second heads	\$6.00 - \$6.50
Long grain parboiled - 1st fancy	\$11.00
2nd fancy	\$10.25
3rd fancy	\$ 9.50

One barrel (162#) will yield 106 to 115 pounds of milled rice (average 68% yield).

Rice hulls = 30#/barrel

Courtesy of FMC Corporation

Exhibit 8. Milled Rice Grades.

MILLED RICE GRADES - USDA

MAXIMUM LIMITS OF

U.S. Grade	Seeds and Heat Damaged Kernels (Singly or Combined): Total	Seeds and Heat Damaged Kernels (Singly or Combined): Heat Damaged Kernels and Objectionable Seeds (Singly or Combined)	Red Rice and Damaged Kernels (Singly or Combined) (Peck)	Broken Kernels	Price Differential	Usage
	No. in 500 gr.	No. in 500 gr. (1)	Percent	Percent	Cents/cwg	
#1	2	1	0.5	4.0	.50	Small percentage
2	4	2	1.5	7.0	Base $9.00-$10.00	Majority of packaged rice - Domestic and Cuban
3	7	5	2.0	15.0	.25	Domestic - General Foods and Kellog for breakfast foods
4	15	10	3.0	25.0	.50	Export
5	30	30	6.0	35.0		Off grade
6	75	75	15.0	50.0		Very small percentag of total

(1) gr. is the abbreviation for grains.

Courtesy of FMC Corporation

FMC CORPORATION (B)

Rice Sorter Layout

Prepared in the Design Division of the Mechanical Engineering Department by J. Kendell Williams under the direction of Karl H. Vesper. The assistance of Dr. T. E. Roberts and Arthur Slemmons of the Central Engineering Laboratories and John Boyce, S. H. Creed, and Don Chamberlin of the Canning Machinery Division is gratefully acknowledged. Financial support for this study was provided by the National Science Foundation.

On March 24, 1958, Mr. Arthur Slemmons, a mechanical engineer for the Mechanical Section of the Product Development Department of the Central Engineering Laboratories was assigned to supervise the design of the mechanical layout for a new rice sorter. Mr. Slemmons was familiar with some "jury-rig" experiments in rice sorting that had been conducted prior to his assignment to the project. In addition, he had layout drawings of the jury rig hardware and samples of some components chosen as a result of these experiments.

Dr. Roberts prepared design specifications for the sorter in January of 1958 and handed them to Mr. Herbert Brooks, the Project Engineer in the Electronics Section. A copy of the specifications appears in Exhibit 1. The machine was to handle 2,000 pounds of par-boiled rice per hour. Rice would fall against the point of a vertical cone and thus be spread into a falling cylindrical curtain 2 1/2 feet in diameter. Grains would be illuminated by incandescent or fluorescent lights and individually scanned by a mirror-lens-slit system turning at 3600 rpm. A background with reflectance equal to that of good rice would be positioned outside the curtain of rice. Light passing through the 1 mm. by 1 cm. image-forming slit would be received by a photomultiplier tube connected to an electronics unit that would recognize defective rice on the basis of intensity and transmit a signal to a 200 segment spark gap commutator. Each segment would be connected to one of 22 trigger tubes which control solenoid-operated air valves mounted on the outer periphery of the sorter, 3 inches from the curtain of rice. Air blasts from the valves would blow defective grains out of the main flow.

Competitive Rice Sorter

Several of the jury-rig experiments performed at CEL were concerned with detection and rejection of methods used in a competitive sorter manufactured by the Gunson Seed Company, Ltd., of England. The "Sortex Sorting Machine" made by Gunson had been developed after World War II when par-boiled rice increased in popularity among consumers. It operated at an input rate of 20 to 120 pounds per hour, depending upon the quality desired. Rice was fed from a screw conveyor into a hopper located above the feed and detection systems. An aligner beneath the hopper ordered rice into a single stream on a grooved rubber belt. Rice grains falling from the end of the moving belt were individually scanned by a photomultiplier tube and lens system. A background with reflectance equal to that of good grains was positioned behind the rice to prevent the sorter from "firing" at a gap in the stream. Pecky grain reflected less light than good grain, and weaker signals from the photomultiplier triggered the rejection electronics which electrostatically charged a pointer located below the optics system. The pointer charged defective grains shortly after they were scanned. A plate below the pointer was oppositely charged to deflect pecky grains horizontally into a rejected product hopper. Good grains were not charged and fell undeflected into a second

product hopper. The layout of the Sortex machine is described in greater detail in Exhibit 2.

The Sortex machine leased for $750 annually. The capacity of the sorter required installation of many machines in a plant with an hourly processing capacity of 10 to 20 cwt.[1] Johnson Soup Company[2] in Sacramento, California, for example, used 12 machines to sort par-boiled rice prior to its use in their soup products. The total output of the sorters at Johnson's varied between 600 and 1000 pounds per hour.

FMC Sorting Experiments

CEL discovered that the electrostatic separation process had been patented by the Gunson Company and that they were not interested in selling any production rights to FMC Corporation. Dr. Roberts commented, "We were forced to use some other system, and we had quite a research program going to try different methods for detection and separation.

At the beginning of the conceptual design phase of the project, it was decided that the FMC sorter would be a circular machine, with rice entering the machine through a cone designed to spread the rice into a single layered curtain. Dr. Roberts explained, "A circular sorter three feet in diameter would be much more compact than a linear machine ten feet wide." Dr. Roberts had planned on using an optical detection system and noted, "An optical detection system located in the center of the circular machine would always be the same distance from falling grains, while with a linear machine, there might be some corrections necessary at the ends of the line."

CEL's first experiment with separation methods was concerned with a variation on Gunson's electrostatic rejection process. CEL engineers discovered that pointed rotating arm could charge rice falling from a conical feed cone. An optical detection system was not installed on the jury-rig, but the engineers proposed that a mirror mounted on the arm could reflect light from the grains to a photomultiplier located above the mirror on the rotating axis of the arm. An image-forming slit, 1mm. x 1cm., mounted axially above the mirror, would rotate with the mirror, allowing light from a small viewing area to be incident on the photomultiplier. The virtual image of the slit would sweep across the falling curtain of rice. The proposed sorter would have a circular background similar to the Sortex background.

To reject, signals from the photomultiplier would trigger electronics for charging the pointer when defective grain was detected. This experiment was discontinued after CEL engineers decided that patent difficulties would inevitably arise. They also felt that technical difficulties like that of maintaining the 20,000 volt charging voltage in the dusty mill atmosphere detracted from the advantages of this sorting method. The proposed electrostatic sorter is described in greater detail in Exhibit 3.

(1) A weight equal to 100 pounds.
(2) Name fictitious

The next experiment used an air gun on the end of a 1 foot arm spinning at 3600 rpm. The air gun blew defective grains out of a curtain of falling rice. Several different devices for generating the air blast were tried including a solenoid-operated air valve, a gas explosion device, and a capacitor discharge device.

The air valve consisted of a wire wound iron core magnet which was momentarily energized to pull a steel "bullet" away from a valve seat. Air at 10 psi. entered the valve adjacent to the bullet and flowed through a cylindrical hole in the seat. Reduced pressure at the seat caused by air flow around the bullet pulled the bullet back to the seat, shutting off the air flow. The air valve is described in greater detail in Exhibit 4.

The gas explosion device consisted of a 1 cubic inch chamber equipped with a small spark plug which ignited an explosive mixture of methane gas and air introduced to the chamber from a passage in the rotating arm. Hot gas from the explosion was expelled through a nozzle.

The capacitor discharge device consisted of a 1 cubic inch chamber with insulated capacitor plates attached to two opposite chamber walls. Electrostatic discharge across the capacitor heated and expanded air in the chamber and expelled it through an air nozzle. Cool air refilled the chamber as a result of low chamber pressure caused by expulsion of heated air.

With the arm turning at 3600 rpm inside a 2-1/2 foot diameter curtain of rice, the blast generator would have to refire approximately every 44 micro-seconds for defective grains locate 1/4 inch apart. CEL engineers found experimentally that the air blast generators used in the experiments required from 40 to 80 milli seconds to refire. As a consequence, CEL engineers decided to use 200 of the bullet-type air valves located outside the curtain 3 inches from the grains. The valves would be timed with respect to the optical system by a 200 segment spark-gap commutator attached to the rotating optical assembly.

Feeding Experiments

In November, 1957, Mr. R. E. Doughty, a mechanical engineer for CEL, conducted several experiments concerned with feeding rice, peanuts, and rivets.[1] Peanut and rivet experiments were performed to determine whether products other than grain could be fed at rates high enough for application of the proposed optical sorter.

Optics required the rice curtain to be one grain thick. The velocity of the falling grains after leaving the feeding mechanism had to be small enough to allow viewing of all grains in a spiral path around the curtain. The width of the path was the vertical image on the rice curtain of the viewing slot in the optical system. The rice had to fall within ± 1/4 inch of the average trajectory in order to remain in the

(1) "Techniques for the Feeding of Rice, Peanuts, and Rivets at High Rates for Electronic Sorting," R. E. Doughty, FMC Corporation, 1958.

depth of field of the viewing lens system.

Mr. Doughty found that a simple polished stainless steel conical slide with a 25 degree angle between the cone surface and a horizontal line was sufficient for feeding rice in a 1 grain thick curtain. The maximum rice flow rate for such a cone was approximately 55 pounds/hr. per inch of cone arc at the cone base. Mr. Doughty suggested a 30 inch case diameter cone for a flow rate of 2.6 tons per hour. He calculated the velocity of rice grains at several points along the trajectory beyond the cone on the basis of a parabolic trajectory. He also calculated the viewing image length required for viewing at several distances below the lip of the feed cone knowing the rotational speed of the scanning system and the velocity profile along the trajectory. For example, a 1 cm. long viewing slit required that an optical system turning at 3600 rpm scan the grains 3/4 inches below the lip where the velocity of the grains was approximately 30 inches per second.

Mr. Doughty suggested in his report that a 15 inch diameter feed cylinder be situated above the cone to control the flow through an adjustable gap between the lower edge of the cylinder and the cone surface. He determined experimentally that a 7/16 inch gap would provide maximum capacity for the 30 inch base diameter cone.

Feeding experiments for peanuts and rivets were conducted using feed cones equipped with aligning and "singulating" troughs. Color anodized aluminum rivets, for example, were fed from a cylindrical feed hopper into a dozen aligning troughs attached to a 25 degree cone. A vibrator attached to the cone helped order the rivets into single file lines. A machine using this feeder possibly could be used to sort poorly anodized rivets from the main stream. Mr. Doughty discovered that peanuts fed on this type of cone would bunch into groups of 3 to 4, resulting in erratic feeding. He obtained better results with a grooved belt fed by a vibrating aligner which could feed at 65 peanuts per sec., but he felt a multiplicity of belts was not readily adaptable to a circular machine.

Optical Detection Experiments

Shortly after Dr. Roberts had drawn up the sorter design specifications, additional tests were performed on a jury-rig optical system. CEL engineers discovered that the electronics would detect shadows on the background and interpret them as defective grains. The system was also sensitive to grain size. A large pecky grain reflected as much light as a small good grain. Consequently, a two color detection concept was chosen to replace the total reflected light system. The jury-rig test used two photomultipliers equipped with color filters. Light passing through a 1 mm. by 1 cm. image slit was divided by a half-silvered mirror, filtered, and received by the photomultipliers which were connected to an electronics unit that recognized signals from defective grains on the basis of light intensity in two narrowed color bands approximately centered around 600 millimicrons and 1000 millimicrons wavelength.

These wavelengths were chosen so that the difference between the signals of the two photomultipliers was positive when pecky grain was viewed, whereas the difference was negative for good grain. The rejection electronics were adjusted so that only a positive signal would trigger the air valves. A flat black background and light trap outside the rice curtain absorbed incident light. A negligible signal was received from the photomultipliers when no grains were in the viewing area.

The jury-rig tests also indicated that the incandescent A.C. lamps used in the experiment provided uneven illumination which would affect the sorting efficiency when the machine was finely adjusted to detect grain with very small peck. Bill Carney, a Project Engineer in the Electronics Section, suggested that light could be introduced into the sorter from a high intensity spotlight using a lens and mirror located axially above the jury-rig viewing system. The system would use a 1 inch diameter illuminating aperature to provide a spot of light on the curtain coincident with the 1 mm. x 1 cm. virtual image of the viewing slit. Louis Thayer, an Application Engineer, suggested a 200 watt, 30 amp locomotive headlamp as the illumination source. The envelope dimensions for the spotlight and photomultipliers are given in Exhibit 5. The jury-rig sorter is described in greater detail in Exhibit 6. Approximate manufacturing or purchasing costs for important components selected for the development model sorter are noted in Exhibit 7.

Sorter Layout

Mr. Slemmens noted several problems for solution during the layout of the development model sorter. Since there were 200 air valves, he felt that the jury-rig valve design should be modified for production on an automatic lathe. He also noted that the extension of the jury-rig scanning head to accomodate the illumination lens and mirror might add to problems of balance and vibration. He said, "The angled mirror, for example, results in unbalanced moment on the head spinning at 3600 rpm. Careful calculations will have to be made to provide for balancing of the scanning assembly after the design had been determined.

CORPORATE OFFICE

FOOD MACHINERY AND CHEMICAL CORPORATION

SAN JOSE, CALIFORNIA

INTER - OFFICE MEMORANDUM

DATE: January 6, 1958

SUBJECT: Whirlwind Separator
CE Project 9509

FROM: T. E. Roberts, Jr.

TO: H. B. Brooks

cc: H. A. Oldenkamp
W. J. Adams, Jr.
W. S. Thompson
L. Thayer

The final objective of CE Project 9509 is to construct one model of a circular scanning machine for sorting parboiled rice. The immediate tasks are to perform the work required to complete Steps 1 and 2. Louis Thayer has accepted responsibility for completing the market analysis required in Step 1 and he will complete this investigation by February 15th.

Your assignment is that of Project Engineer for Steps 2-5. Since this project is the most important that we have undertaken in electronics, you should plan to devote your full attention to this project for at least the next two months. After two months or so the project may be organized in such a way that you could pick up other assignments.

Your efforts should be confined to Step 2 work until a project cost estimate for Steps 3-5 has been made and approval obtained to continue into this work.

The objectives of Step 2 for this project are:

1. Jury rig tests of untried principles.
2. Study layouts.
3. Engineering cost estimate for complete project.
4. Manufacturing unit cost estimate.
5. Market analysis (assigned to Thayer).
6. Preparation of a report and appropriation request.

You should first form a plan for carrying out Step 2 and make the basic decisions concerning the required jury rigs, whether a complete rotating assembly is needed, what electronics should be bread-boarded, etc. Then determine whether the present appropriation is sufficient for this work.

The engineers available for this project are:

H. B. Brooks	B. M. Carney	R. E. Doughty (1/2 time)
V. O. Blackledge	T. E. Roberts (1/4 time)	

If you can develop a good program around these people, fine. Otherwise we can make the required changes.

Attached are general specifications for the machine. Please suggest changes that you feel are desirable.

TR

T. E. Roberts, Jr.

TER:jk
Attach.

Exhibit 1. Design Specifications.

WHIRLWIND SEPARATOR SPECIFICATIONS

I. Product

The product is parboiled rice to be handled at the rate of one ton per hour. This is about 15,000 grains per second. Up to five percent of the product may be defective.

II. Mechanical Arrangement

The mechanical layout will be for a circular machine in the manner layed out by Doughty. The rice flow cylinder should be 2 1/2 feet in diameter with a background 3 inches behind the rice. The design should be such that rice cannot accumulate anywhere within the machine.

III. Scanning

The scanning should be done by rotating a lens-mirror system at 3,600 r.p.m. This implies a linear scan rate of 14,300 centimeters per second. If there is one rice grain per square centimeter in the rice flow cylinder, this will give about one ton per hour.

IV. Optics and Electronics

The optics should carry the light signal from a slit 1 mm.x 1 cm. to a photomultiplier tube. The photomultiplier output should go into an electronic unit that recognizes defective rice and transmits a signal to the commutator. The pulse width for a small defect will be 1/143,000 sec. so that an electronic bandwidth of 143,000 cps. will be about optimum. (This will allow considerable noise from the photomultiplier. Some type of automatic stabilization of the circuit sensitivity should be included. Lighting will be by use of 3 circuline fluorescent tubes or indirect incandescent.

V. Commutator

The commutator will be of the spark-gap type with 200 segments. A synchronizing signal may be required for the modulator that generates the signal for the commutator. This can be obtained from a disk and phototube.

VI. Reject Mechanism

The rejection shall be by use of air controlled by solenoid-operated valves. The solenoids will be controlled by a 5823 cold cathode trigger tube, the grid of which is connected to a commutator segment. A high resistance will be in the commutator "brush" to prevent overloading the 5823 grid. The reject mechanisms are to be mounted on the outer periphery of the machine.

VII. Motor Drive

There are several advantages to the use of a synchronous motor drive. This should be considered.

VIII. Physical Arrangement

Whenever practical all parts should be accessible. In the first model it would appear that the electronic components and power supplies should be in a standard 19-inch rack.

IX. Design Standards

The general design should be conservative and the reliability equivalent to that which can be obtained through use of standard components. No special effort should be made to use high reliability components or to use plug-in components. There will be a re-design in Steps 5-9 for high reliability. In cases where there may be trouble-shooting problems, i.e., 200 reject channels, a test procedure should be established and the required feature designed into the machine.

Prepared by: T. E. Roberts, Jr.
January 6, 1958

TER:jk

Exhibit 2. Sortex Layout.

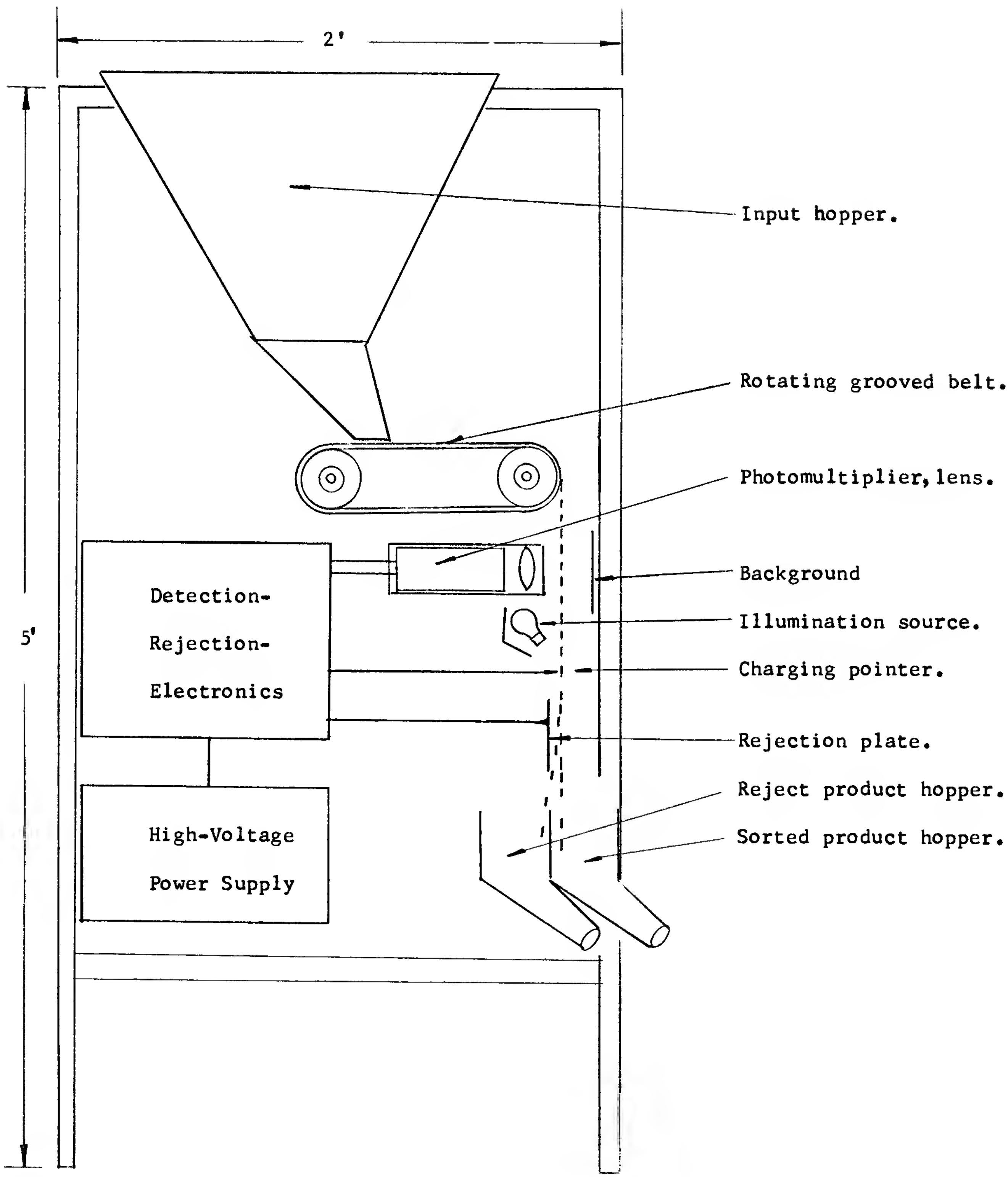


Exhibit 3. Electrostatic Rejection Sorter.

ECL-17
M.E. 114a-3

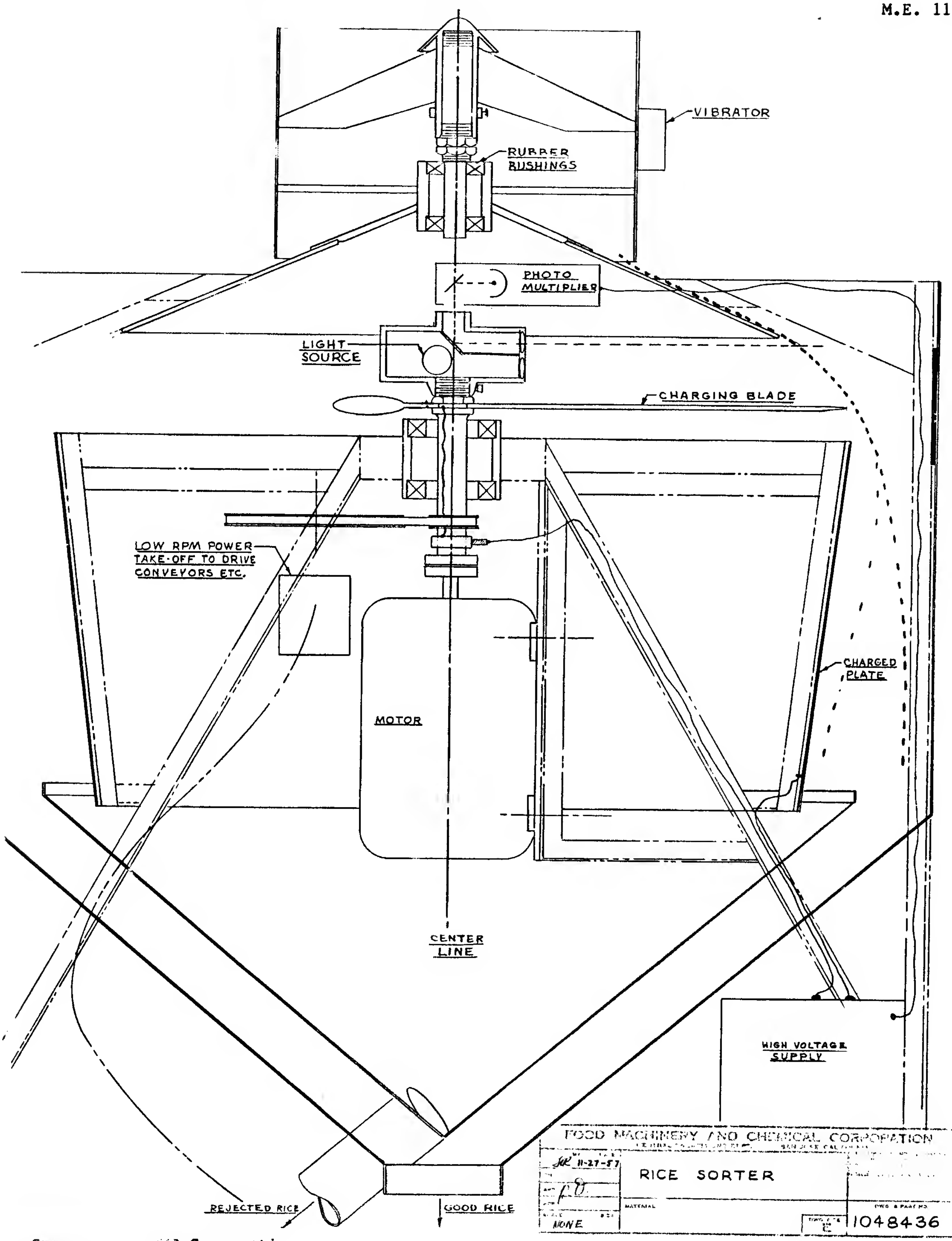
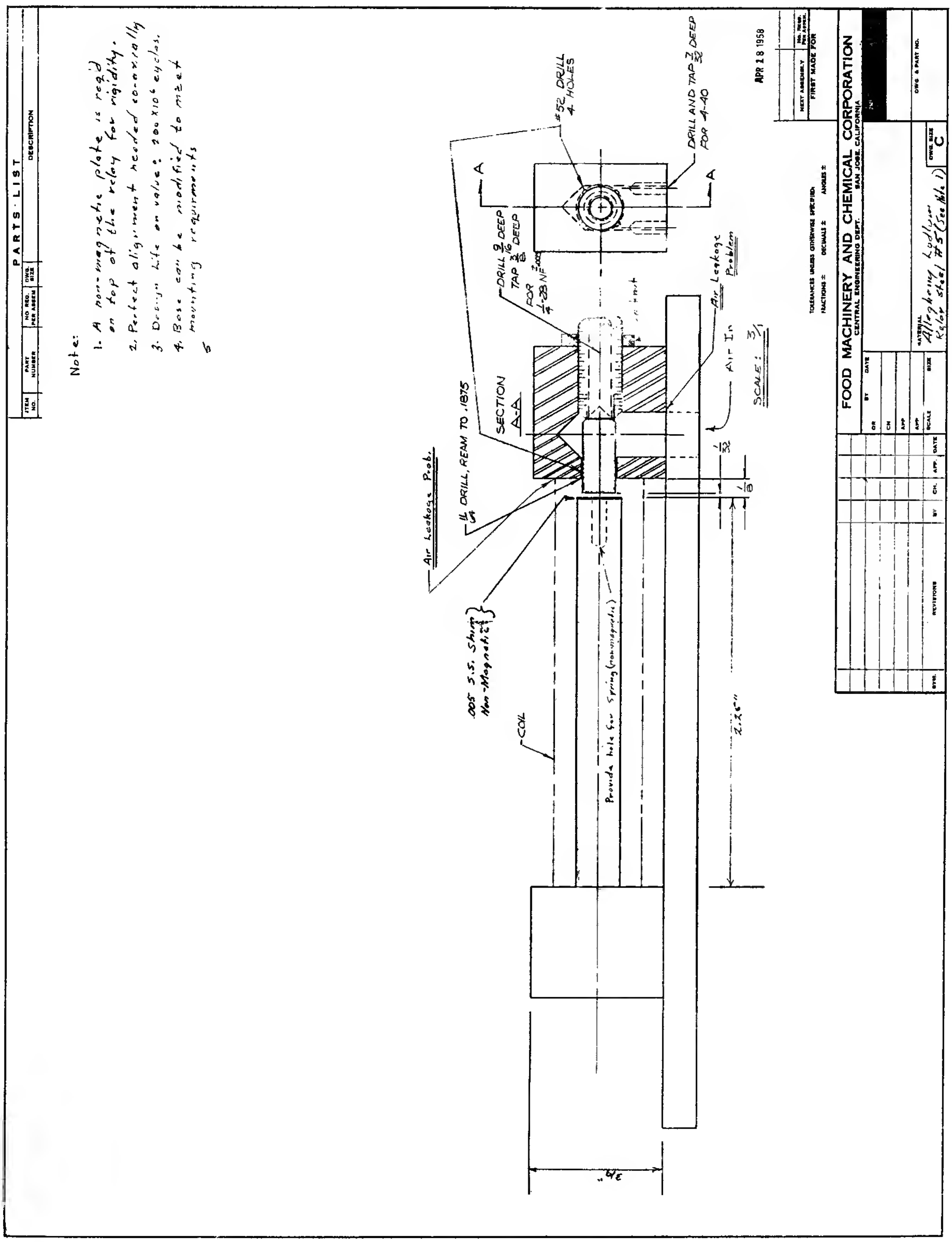
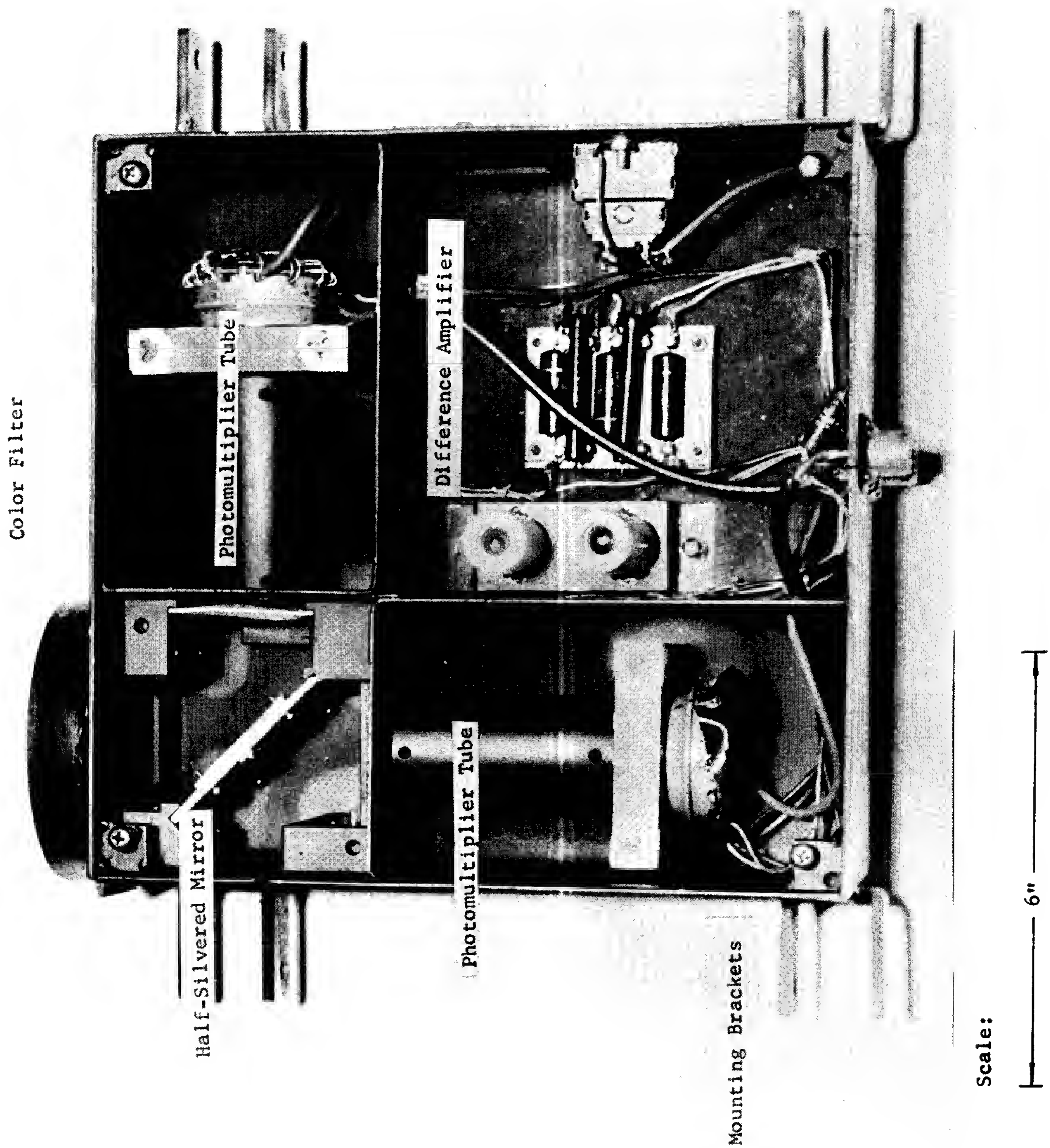


Exhibit 4. Jury-Rig Air Valve

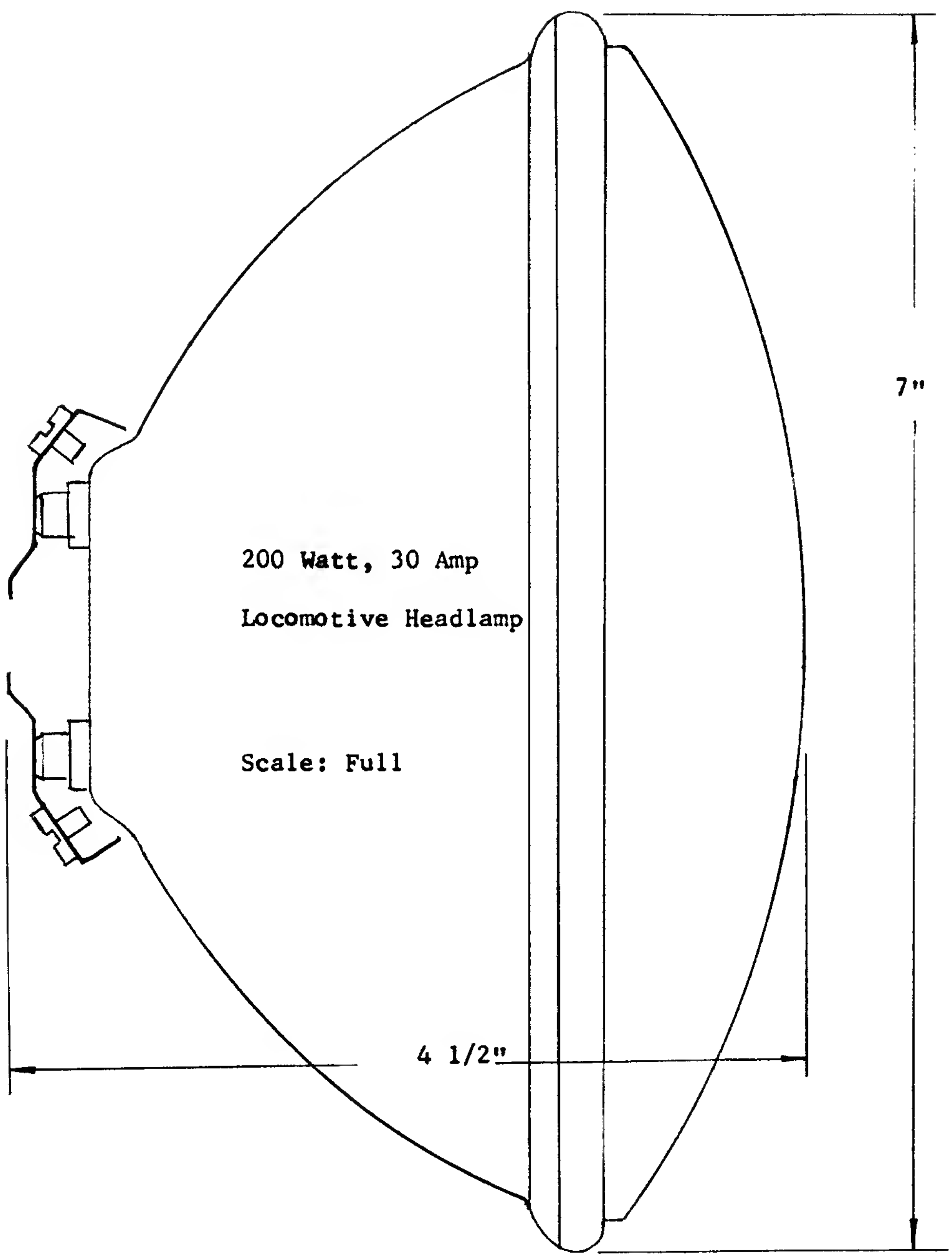


Courtesy of FMC Corporation

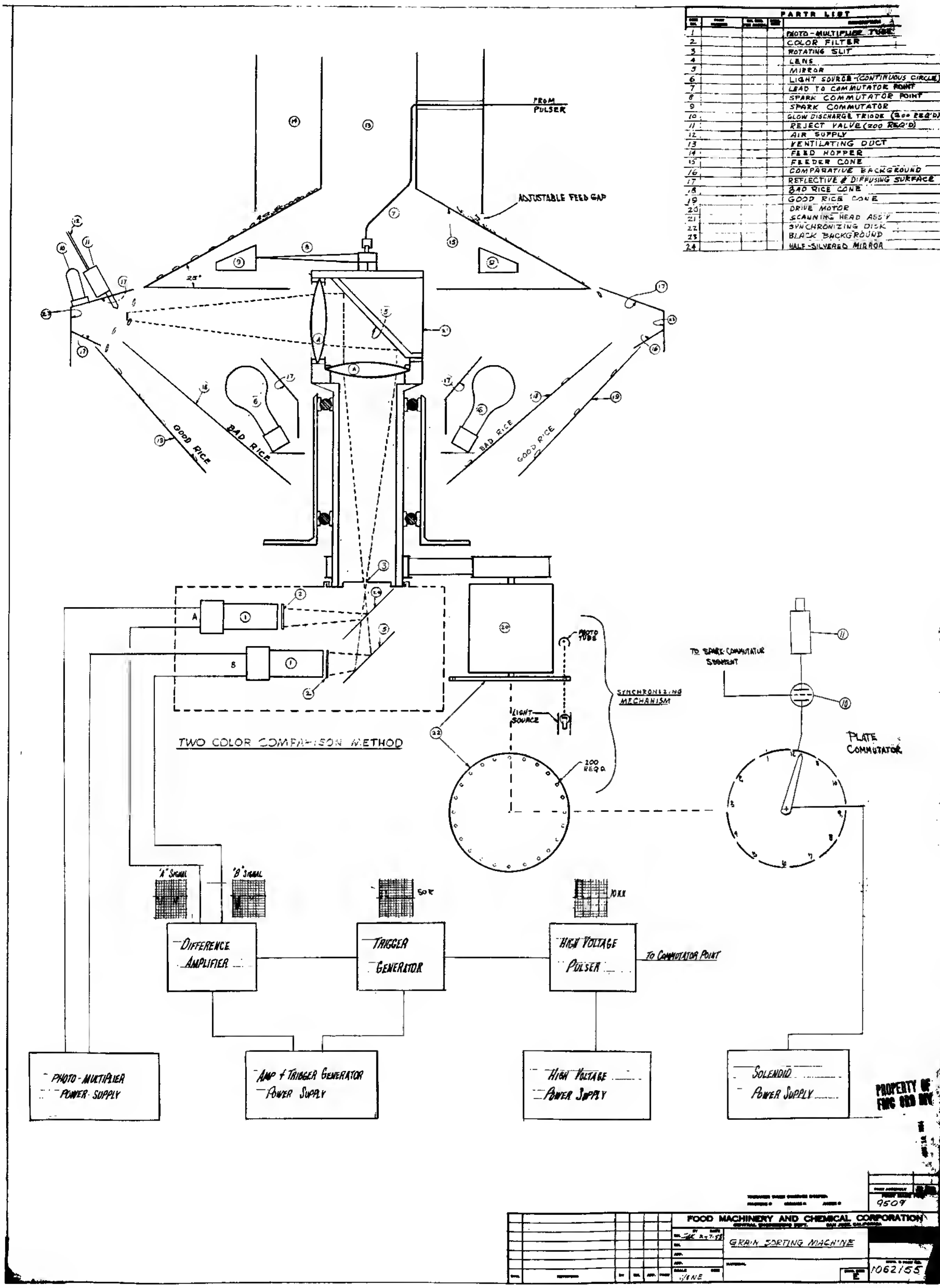


Courtesy of FMC Corporation

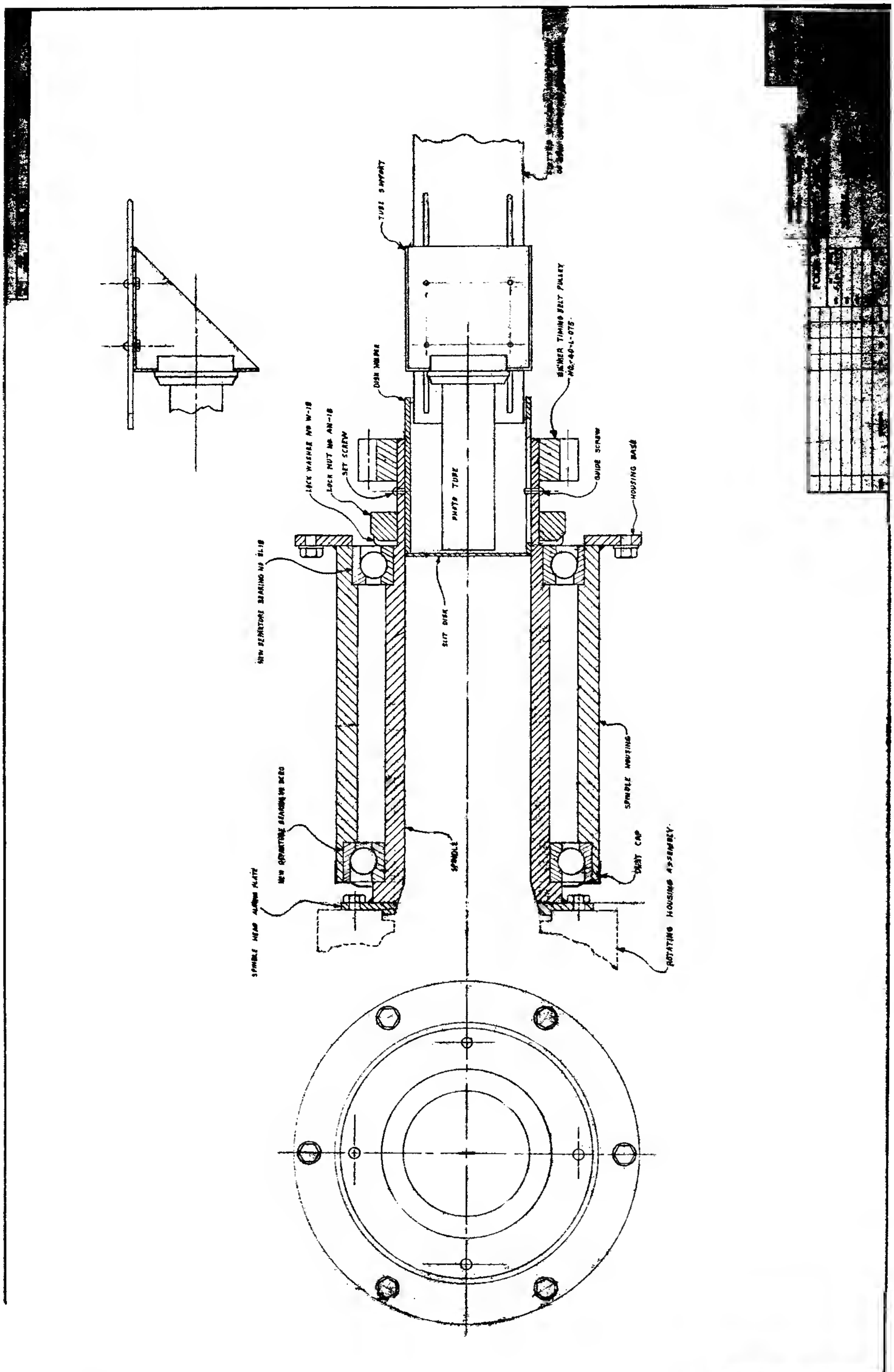
Exhibit 5. Component Envelope Dimensions



Courtesy of FMC Corporation



Courtesy of FMC Corporation


TUBE SUPPORT
PHOTO TUBE
SET SCREW
GUIDE SCREW
HOUSING BASE
SLIT DISK
SPINDLE HOUSING
SPINDLE
DUST CAP
ROTATING HOUSING ASSEMBLY

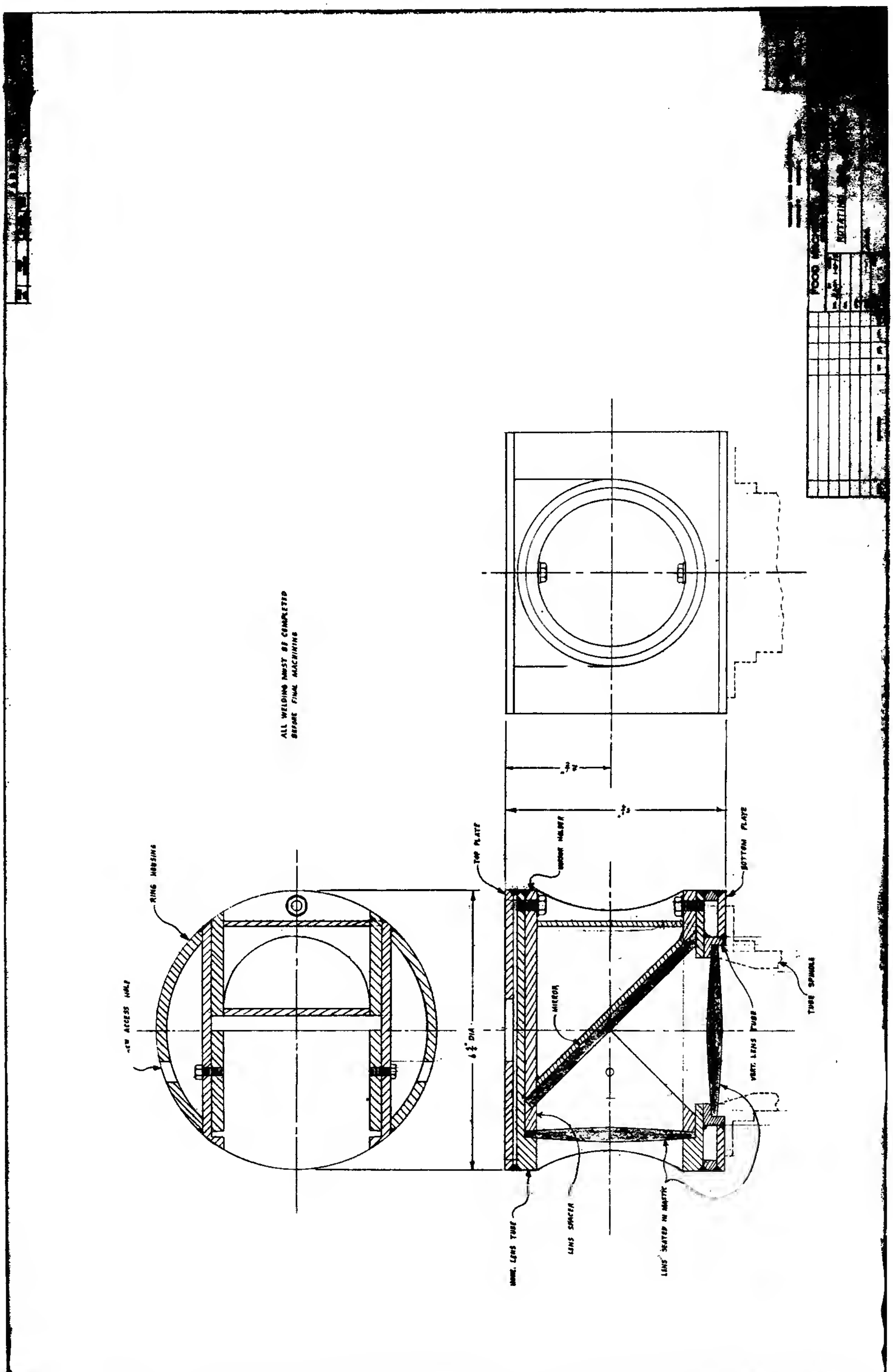

ALL WELDING MUST BE COMPLETED
BEFORE FINAL MACHINING
RING HOUSING
TOP PLATE
BOTTOM PLATE
MIRROR
TUBE SPINDLE
VERT. LENS TUBE
LENS SPACER

Exhibit 7. Jury-Rig Sorter Costs

Note: The cost figures listed below include material, labor, and burden charges except on purchased items.

Exhibit 6 Part No.	Part Description	No. Req'd	Unit Cost
1a	"Blue" Photomultiplier	1	$ 55.00
1b	"Red" Photomultiplier	1	$ 110.00
2	Color Filter	2	$ 10.00
4	Lens	2	$ 100.00
5	Mirror, Front Surfaced	2	$ 26.00
7,8,9	Commutator Assembly	1	$ 635.00
10	Glow Discharge Triode	200	$ 0.75
11	Reject Valve	200	$ 22.00
20	Drive Motor, 1 Hp.	1	$ 75.00
21	Scanning Head Assembly	1	$1000.00
24	Half Silvered Mirror	1	$ 30.00

FMC CORPORATION (C)

Mechanical Failures in a Rice Sorter

Prepared in the Design Division of the Mechanical Engineering Department by J. Kendall Williams under the direction of Karl H. Vesper. The assistance of Dr. T. E. Roberts and Art Slemmons of the Central Engineering Laboratories and John Boyce, S. H. Creed, and Don Chanberlin of the Canning Machinery Division is gratefully acknowledged. Financial support for this study was provided by the National Science Foundation.

In September, 1963, Don Chamberlin, an engineer for the Canning Machinery Division of FMC Corporation, faced the task of eliminating problems that had occurred in four rice sorting machines which had been leased to the Consolidated Rice Company,[1] and installed in their plant in Houston, Texas. Consolidated's engineers had difficulty timing the sorter because Electronic trigger tubes controlling the rejection air valves sometimes would fail to extinguish. Also, three cases of scanning spindle bearing failures had each resulted in several hours of down-time during the September through November harvest season. Oil mist from the bearing lubricators and rice dust were collecting on the optical viewing shield, requiring cleaning every two hours during peak operating periods or installation of a clean shield which required 15 minutes of down-time. When Consolidated's managment requested assistance from FMC, Don Chamberlin and Bill Myers from the Canning Machinery Division and Bill Carney from the Central Engineering Laboratories flew to Houston in mid-September to determine the reasons for the problems. The operation of the sorter is described in Exhibit 1.

When Don Chamberlin returned, he described these problems in a memo to the Assistant Chief Engineer, Mr. S. H. Creed. The memo appears in Exhibit 2. Don felt that the failure of the upper spindle bearing was the most significant difficulty encountered and stated,"If the bearing fails, the machine can't do its job at all." Don did not know the reason for the bearing failures, although he suggested that assembly practices, lubrication problems, and rice dust in the bearing were possible contributing factors.

CANNING MACHINERY DIVISION

In January, 1959, the Canning Machinery Division was chosen by Corporation officials as the division best suited to carry through design of a production model of the rice sorter and sponsor Step 6 through Step 10 of the product development program.[2] The intended applications of the sorter were in food processing, and CMD[3] with its national sales had developed close relationships with major food processing companies.

Founded in 1952, CMD consisted of two major operations, one located in San Jose, California, and the other in Hoopeston, Illinois, each with major plant facilities and sales offices. The San Jose plant, employing approximately 50 mechanical engineers, was selected to proceed with the project because of its proximity to the Central Engineering Laboratories. Facilities of the 100 acre plant included a large machine shop, sheet metal fabricating and finishing shop, and three assembly bays each with approximately 30,000 square feet of floor space. Each engineer at CMD was associated with a particular project or type of machinery. The engineers developed basic product ideas, designed production equipment,

(1) Name fictitious
(2) Refer to Exhibit 3, FMC Corporation (A)
(3) CMD is the abbreviation for Canning Machinery Division

and assisted in field testing of Division products. In addition, they frequently did development work on machinery designs for outside companies. CMD products included fruit and vegetable harvesting and processing equipment, atmospheric and pressurized continuous can cookers, and dairy packaging and filling equipment.

Don Chamberlin graduated from San Jose State College in 1959 with a B.S. degree in Engineering. His studies included electronics, materials and production processes, as well as mechanical design subjects. He said, "You have to study a lot of material in school that has uncertain value at the time and learn some things you feel can't be applied on the job." He enjoyed laboratory work in school and felt that his early interests in mechanical things had been helpful in later work. Don Chamberlin's hobbies included electrical and mechanical "tinkering" at home.

When he was assigned to the sorter project, Don Chamberlin had been working for CMD for five years. His first job with CMD was detail designing performed on a part-time basis while attending San Jose State College. Shortly thereafter, Don became interested in pear handling equipment and was asked by the Assistant Chief Engineer to come up with new ideas for pear aligners and feeders used with pear coring, pealing, and slicing machines. Don developed his ideas with mock-ups and eventually tested several aligners in the field. Don said, "To take a machine out in the field and run it under really adverse conditions is a broadening experience. I became much more conscious of what would and wouldn't work under such conditions." Don's ambition was to eventually be a project engineer.

Transfer of the Sorter Project

The design of the developmental model rice sorter by the Central Engineering Laboratories had proceeded over a four year period. During this time, eight engineers had worked on the project, including five electrical and three mechanical engineers.

In June, 1959, tests of the development model sorter were conducted at the Johnson Soup Company[1] plant in Sacramento, California. The tests were organized to determine the reliability of the sorter under operating conditions and were part of the Laboratories' responsibility under Step 5 of the development program. On June 11, 1959, the sorter operated for one hour at the rate of 1100 pounds per hour, and removed 85% of the pecky grains from the stream. The laboratory continued to perform tests at Johnson Soup in Sacramento and Consolidated Rice in Houston, Texas, during July of 1959.

[1] Name fictitious

In August, 1959, CMD assigned a project engineer to the rice sorter project and assumed financial responsibility for the remainder of the product development project. The project engineer from CMD worked closely with the engineers from CEL[1] during the design of the production model sorter.

Development and Production Model Design Differences

There were several major mechanical differences between the development model sorter and the production machine. A typical example was the support structure. Dr. Roberts noted, "The structure of the development sorter was designed with a number of individual members welded together to achieve light weight and ease of manufacture for the first test model. CMD made theirs from a piece of steel plate rolled into a tube, which is the way that they make a lot of their equipment." The development model sorter was approximately 9 feet tall. The height of the production model was set at 7 feet, 8 inches by the project engineer so that the sorter would fit through the 8 foot door of a standard railroad freight car. The design of the development model sorter is described in greater detail in Exhibit 3.

Another example was the design of the feed cone. The development sorter initially used a sheet metal cone with a 30° angle between the surface of the cone and a horizontal line through the apex. Dr. Roberts said, "We didn't do enough experimenting and consequently found out after building the machine that rice would flow by the air valves too fast. When the cone angle was decreased to 25°, the slightly oil rice grains would stick to the cone surface." Electromechanical shakers were installed on the underside of the cone to help smooth out the rice flow, but the vibrators formed waves in the cone surface which caused nonuniform feeding. The problem was solved by a technician working on the sorter project in the test laboratory. He had been experimenting with a piece of window screening and discovered that rice would stop motionless after hitting the screen. Further experiments conducted on the development model with screen and other material led to the design of 0.005" thick sheet metal baffles placed around the edge of the 30° feed cone of the production model sorter. The baffles are described in greater detail in Exhibit 1, page 10.

There were major differences between the two machines in the design of the product collection hoppers. Both models had two concentric hoppers separated by a divider baffle. The development model hoppers had individual bottom plates. Each plate sloped at a 45° angle to a product ejection chute. During the operational tests, it was discovered that rice pilled up in the sorted product hopper. Dr. Roberts said a special chute was attached to the hopper in order to continue with tests. The product hoppers of the development model are described in greater detail in Exhibit 3, page 2.

---

[1] CEL is the abbreviation for Central Engineering Laboratories

The first design of the hoppers on the production model consisted of two concentric cylinders seated against a driven rotating bottom plate designed to push the rice into scoops which projected into each hopper. The hopper walls, scoops, and divider baffle were sealed against the bottom with felt or rubber wipers. This feature is pictured in Exhibit 1, page 8. When engineers discovered that the pecky grains were getting into the sorted rice hopper by squeezing under the wipers, the design was changed to include rotating product discharge brushes which pushed the rice into a large opening for a product chute attached to the fixed bottom of each hopper. The discharge brushes and product chutes are pictured in Exhibit 1, page 6.

The spindle bearings of the development model sorter were pressed into the spindle housing, whereas the production model used bearing retainer clamps to facilitate assembly of the spindle and housing. Mr. Slemmons of CEL commented, "I feel that it is necessary to press the bearings into the outer housing when the inner race supports an unbalanced load, as in the case of the scanning spindle. In this case, the load remains in fixed position to the inner race but constantly shifts with respect to the outer race as the spindle turns. A clamped bearing may tend to walk and vibrate with the changing load if there is any dirt between the clamp and bearing face. It is often necessary to use a torque wrench to insure even clamping pressure."

Production Model Bearing Problems

When Don Chamberlin was assigned to the project in 1962 as a design engineer, the Canning Machinery Division had produced five production model rice sorters and was in the early stages of manufacturing three additional sorters. The first, third, fourth, and fifth machines were installed at Consolidated Rice Co., Inc., Houston, to sort pecky grains from the rejects of their mechanical sorters. The second sorter was installed at the Valley Vegetable Packers, Inc., plant in Modesto, California to sort dried and diced carrots.

The bearing problem had occurred previously on the first rice sorter at Consolidated. The trouble was evidenced by a high pitched "howl" from the machine, which, Don said, would have eventually ended in failure of the spindle bearings. The project engineer at that time attempted to solve the problem by changing the lower ball bearing on the spindle to a roller bearing, which allowed axial movement of the inner race relative to the outer race. Don stated that this eliminated the possibility of (1), axial pre-loading of the bearings during assembly, and (2) axial loading of the bearings during operation due to thermal expansion between the spindle and spindle housing. The assembly of the bearings is pictured in Exhibit 4. Dimensions and tolerances of parts in the scanning head assembly are given in Exhibit 5.

Don's first assigment was to implement the bearing change during a field trip to Houston in August, 1962. The trip had been organized to give him familiarity with assembly of the machine. The bearing change was also made on the machine at Modesto and incorporated on the three sorters being manufactured for Consolidated.

When Don returned from Houston in September, 1962, he felt that additional changes in the mechanical design of the sorter were necessary, particularly in the area of the upper scanning spindle bearing. He said, "In one instance, service personnel at Consolidated installed a new upper bearing on the sorter and it failed inside one week!. This occurred when they were operating on a 24 hour basis." The upper bearing was a New Departure No. 73L22 light-weight ball bearing, shielded on one side only. This bearing is described in greater detail in Exhibit 6, under the 3L22 classification.

The bearing lubrication used in the sorter was an Alemite oil mist lubricator, which consisted of an oil reservoir and atomizing pump which forced oil mist through 1/4 inch copper lines to the bearings. Don said that the mist system was used to help keep electronics and commutator parts dry by reducing mist flow-rate to a point where only a thin film of oil formed on the balls. The oil mist unit is shown attached to the sorter base in Exhibit 1, page 7.

The function of the scanning spindle was to support and rotate the scanning head which carried mirrors and lenses for sweeping the beam of light over the curtain of falling rice. The spindle rotated at 3600 rpm and was supported by ball bearings at the upper end and by roller bearings at the lower end. The bearings were in turn supported by a cast spindle housing which joined with the base structure of the sorter. A spark gap commutator to time the reject valves was attached to the housing and spindle. The spindle was connected to the drive motor by a cogged timing belt. The assembly of these parts is described in greater detail in Exhibit 4, page 1.

Don felt that rice dust in the upper spindle bearing was causing the bearing failures. He noted that the evidence supporting his conclusion was primarily the presence of an oil-dust sludge found in an upper spindle bearing which failed at Consolidated in September, 1963. Don said that the installation of the roller bearing had not eliminated the bearing failures. Don approved of the addition, however, and stated, "It was not good practice to fix the bearings through two different paths."

Don said that approximate bearing lifetime calculations had been made, but commented, "That bearing should have lasted for sixty years!" To help determine the reason for the bearing failures, a manufacturer's representative for the New Departure Division of General Motors Corporation was called. The representative noted the conditions under which the bearing was operating, including Don's comment that rice dust was getting past the dust shields located over the upper bearing. This information

along with several failed bearings was sent to the New Departure plant in Bristol, Connecticut. Bearing specialists there performed an analysis of the bearings, a summary of which is included in Exhibit 7.

Don was surprised by the bearing analysis. No mention was made in the report of any possible effect of the rice dust in the bearings. Contrary to the report, he felt that the bearing was not being excessively radially pre-loaded. "The installation involved a light press fit," he said, "and I specifically mentioned to the New Departure people that the outer race was clamped in our application. This is one of those times when an engineer should season a suggestion with some of his own analysis and intuition."

Don noted several design weaknesses in parts of the spindle area that might have contributed to the bearing failures. The previous project engineer had installed dust deflectors above the upper spindle bearings. The lower half, part no. 688068, retained the bearing and provided a dust shield. The upper half of the assembly, no. 689380, was added later to provide additional dust protection. The deflectors were made of aluminum, and Don thought it possible that aluminum filings formed by abrasion with the spindle could get into the upper bearings. He also noted that the original parts drawings made no notation of any parallel tolerance between the bearing lands. An adapter forming one bearing land was bolted to the main spindle. Don noted that it was possible to have non-paralleled lands, and said, "You have to have parallel lands to insure proper operation."

In approaching the problem of eliminating the bearing failure, Don said, "I would redesign everything that might contribute to the problem. A lot of the design was not well thought out simply because it became necessary to solve a problem quickly by adding to the design. It's very difficult to get someone to back up and do it properly." Don noted that cost as well as reliability considerations were important to the design of the sorter, and that it was desirable to keep the number of new parts to a minimum. Cost figures for several parts in the spindle area are given in Exhibit 8.

Commutator Problems

Don worked alongside the production workers when the three production models were being assembled to insure that care was used during the assembly of the bearings. When the commutator was being installed, he discovered another problem. It was difficult to maintain concentricity between the commutator rotor pointer and stator needles. A check of concentricity with a feeler gage was required during assembly and also later when the machine was timed in the processing plant to improve sorting performance.

The function of the commutator was to distribute at the proper instant a signal from the optical detection system to the trigger tube controlling the air valve adjacent to a defective grain. A 10,000 volt pulse signal from the high voltage power supply was conducted by a spring loaded carbon brush in the stator to a metal slip ring in the rotor. A single rotor

pointer distributed the signal across a 0.005 to 0.008 air gap to one of 198 stator needles, each of which was wired to one of six electrical connectors on a metal frame attached to the base of the sorter. Cabling from the connectors led to six banks of trigger tubes mounted adjacent to the air valves.

The commutator stator was attached to a "commutator spacer" with six socket head cap screws which passed through elongated holes in the stator body. The elongated holes allowed the stator to be rotated relative to the housing, while a "concentricity guide" centered the stator. The guide was mated to the stator body with a close fit and held in position by a set screw. The stator was secured to the spindle housing by socket-head cap screws. The commutator stator and rotor assemblies are described in greater detail in Exhibit 4. Details of the commutator parts are included in Exhibit 5.

The sorter was timed by removing four trigger tubes for air valves located 90° apart. Each firing space could be tested in relation to its air valve by placing a 1/16 diameter sitck into the optical path radially in front of the valve air vane and moving the stick from side to side with the detection system and spindle operating. The limit of the firing space was indicated when an adjacent air valve fired. If all the spaces were off in the same direction, clockwise or counter-clockwise, the stator was rotated to properly align the firing spaces in relation to the air vanes. If the firing spaces were displaced in opposite direction, this indicated a radial displacement of the stator or reject manifold.

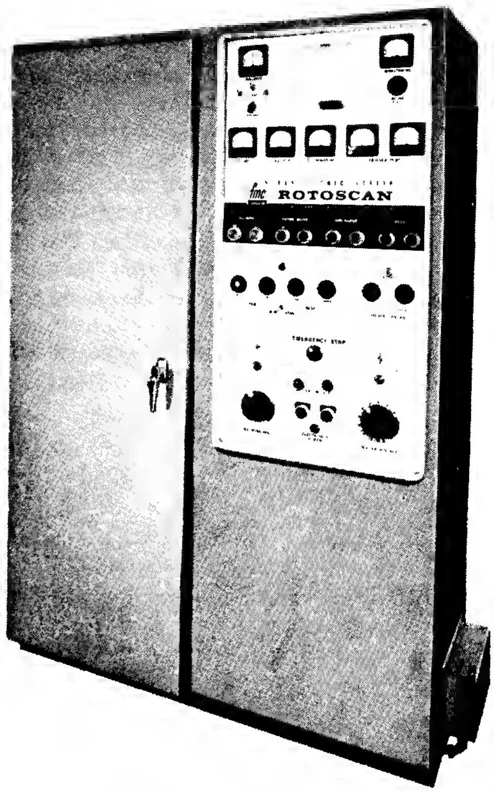
In addition to timing, other commutator maintenance included inspection of the carbon brush, sharpening of the rotor pointer, and cleaning of the stator needles every seven days with a soft brush to remove rice dust. Maintenance was reduced somewhat by a shield or "slinger" which was attached to the spindle immediately above the commutator to throw oil mist and rice dust out of the space between the housing and stator through openings in the base of the housing. Oil drains were located around the outside of the stator to draw off condensed lubricant. High pressure air was supplied to the commutator through air fittings located above the stator needles to keep dust off the needles. In addition, a plastic ring was located below the carbon brush to collect dust particles. This assembly is described in greater detail in Exhibit 1, pages 11, 12, and 13.

Don said that because of the high selectivity of the spark between the rotor pointer and the stator needles, a concentricity tolerance of 0.002 T.I.R. between the pointer and needles was required to insure that the proper air valve was fired when a reject was detected. He said that it had not been possible to achieve this tolerance without considerable difficulty in positioning the stator with respect to the spindle housing. When the concentricity was 0.010 T.I.R., the commutator signal was strong to one side of the sorter and weak to the other. The fluctuating signal and impaired timing dropped the sorter efficiency 5%. Don said that 0.002 T.I.R. was the most practical concentricity that their machine shop

could hold on the housing and commutator parts without resorting to special tooling. He noted that radial play in the roller bearing could contribute to the difficulties by allowing the spindle to be pulled sideways by 0.003 inches when the cogged drive belt was slack. However, Don said, "Standard replacement parts like the commutator assembly and bearings should remain interchangeable with the new and old designs. We would also like to keep the number of new parts on the machine as low as possible and still solve the bearing failures and commutator alignment problems. Failures add considerable down-time to maintenance of the machine and detract from the Division's integrity."

FOOD PREPARATION AND PROCESSING EQUIPMENT

FMC ROTOSCAN SORTING MACHINE



Purpose

The FMC Rotoscan Sorting Machine is designed for electronically inspecting and sorting small, free-flowing, granular and flake products in a lightning-fast, efficient and continuous operation.

Products, Uses, Application

Many products from which off-color and foreign material must be removed, lend themselves to Rotoscan sorting, such as rice, dehydrated diced vegetables, dried beans and grain. This machine employs a combination of mechanical, optical, electronic and pneumatic principles to accomplish the scanning and sorting. In a typical operation, the Rotoscan would be placed in the final inspection line prior to packaging. It may also be used for initial line inspection at the source of product input.

Features and Advantages

Reduced Labor Costs—reduces sorting labor requirements. Also in some applications (such as diced vegetables) may eliminate or greatly reduce the trimming labor now used to trim the whole product. In this application the Rotoscan would separate the defects from the diced or dehydrated product.

Increased Yield—elimination of product waste inherent in hand trimming operations may result in increased yields.

High Capacity—as high as 5,000 pounds per hour on some rice. Capacity varies with the degree of defects present in the product, and the degree of separation desired.

Upgraded Product—removal of off-color material by machine may result in a higher grade of finished

Courtesy of FMC Corporation

Exhibit 1. Sorter Operation

product. Sorting is consistent and uniform. No reduction in efficiency such as is prevalent in a manual operation.

Simplicity In Design—manufactured in three basic removable sections for ease of service and modifications. Independent removal of upper frame section lends itself for replacement to a modified assembly to accommodate products requiring a different feed arrangement.

Quality Control—efficient sorting and quality control adjustment is provided to allow for product variation.

Construction/Operation

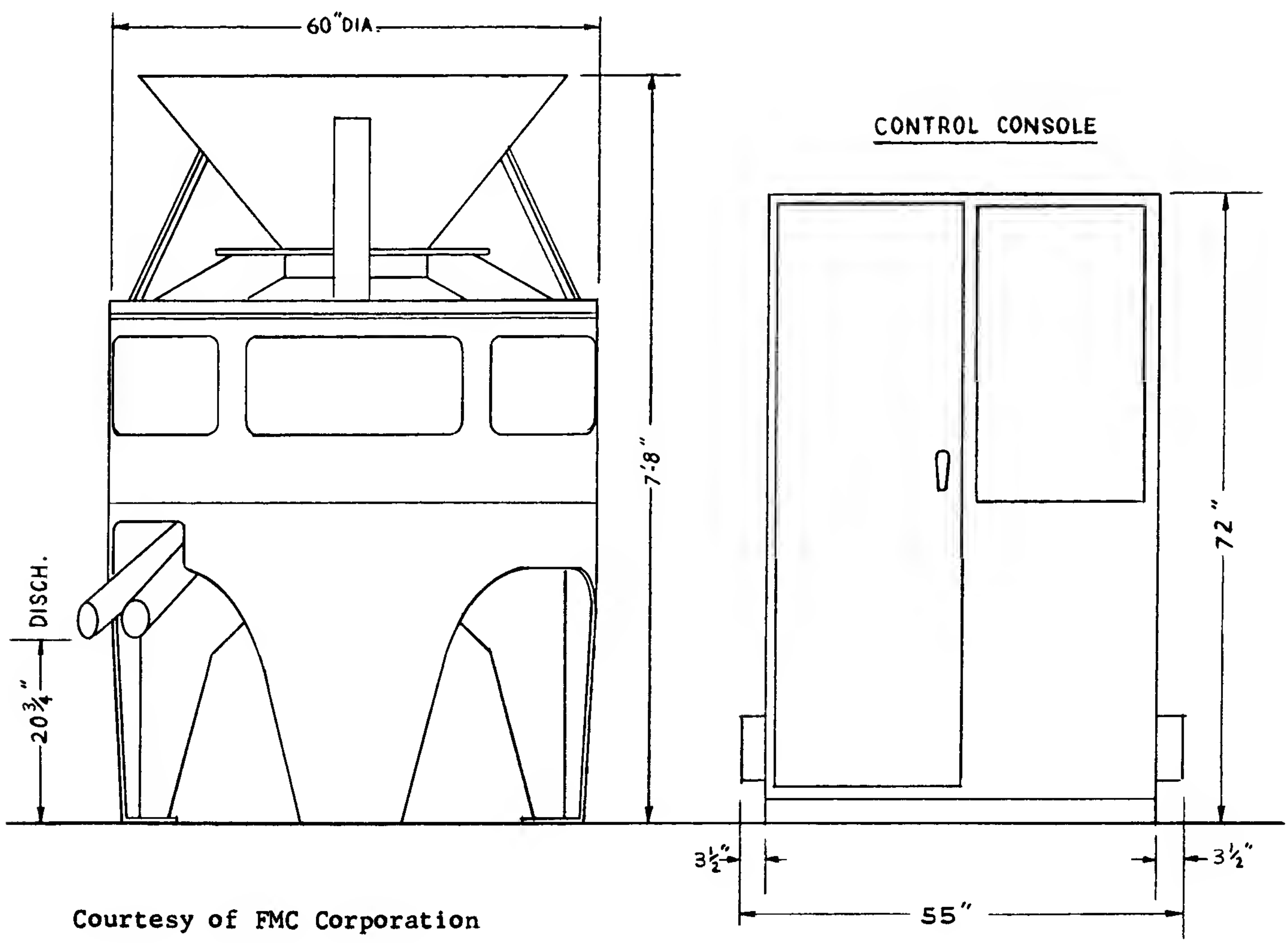
The FMC Rotoscan is comprised essentially of a feeding arrangement, a viewing system, and a rejection system mounted on a heavy fabricated steel base. Moving parts are dynamically balanced to provide a vibration-free operation. Automatic controls for the Rotoscan are housed in a console-type cabinet.

In operation, the product is fed from the hopper through a revolving flow-control gate and cascades over a metal cone for even, circumferential distribution in a thin layer preparatory to scanning. Scanning of the product takes place instantaneously. At the discrimination of the scanning device, the desirable product flows undisturbed to the proper discharge channel. Defective particles transmit a signal to one of 198 air valves mounted around the circumference of the machine. This actuates a blast of air that blows the undesirable particle over a dividing partition into the reject chute.

The scanning head optic viewer rotates approximately 58 revolutions per second which enables it to detect undesirable particles at an extremely rapid rate.

Specifications

Height Overall	92″
Width Overall (diameter)	60″
Capacity: Up to 5,000 pounds per hour on some rice	
Product Discharge Height	20¾″
Product Feed Height (approx)	92″
Motor HP Required:	
Main Drive	1
Feed Drive	1/4
Discharge Drive	1/2
Cubic Feet (approx)	122
Console Control Unit:	
Height Overall	72″
Width Overall	55″
Depth	21¼″



Courtesy of FMC Corporation

ELECTRONIC SORTER

ROTOSCAN

FMC ROTOSCAN

GENERAL DESCRIPTION

Function of the Machine

The Rotoscan Electronic Sorter is a Machine for optically inspecting individual grains of dry products. Off-color or defective grains and off-color foreign bodies are removed from the main stream and allowed to exit through a reject spout. The Machine handles a continuous flow of material at a rate that depends on the material, nature and concentration of defects and the desired output product quality.

Use is made of mechanical, optical, electronic and pneumatic devices in order to accomplish the separation.

Major Components and their functions

Major components are shown in Figures 1 - 14 and a Block Diagram on Page 16 illustrates the electronic system. Product is fed into the Upper Hopper which maintains a constant head on the Rotating Feed Gate. Product is metered at a rate which depends on the height of the feed gap of this Gate. The particles flow over the Feed Cone (Fig. 14) through a set of Baffles located on the periphery of the Cone. The Cone and Baffle are arranged so as to provide an even flow of material at a uniform velocity. The flowing objects are inspected immediately after leaving the Cone periphery. The material normally flows outside the dividing partition and down to the sorted product exit.

A defective particle is blown inward by air from one of the 198 Reject Valves (Fig. 7 & 14). Such particles flow through the inside collection Hopper and out the Reject Spout (Fig. 1). In order that the proper Valve be actuated, it is required that the particles be successively scanned, reflected light collected and analyzed, a signal generated and commutated to the Trigger Tube that controls the Valve to be actuated.

Illumination is supplied by the Projector Lamp and Condenser Lens system (Fig. 8), located within the Upper Hopper (Fig. 2). This light is transmitted to a Lens and Mirror System in the Scanning Head (Fig. 14), which is part of the Main Rotor turning at 3540 revolutions per minute. Therefore, the Projector Lamp and Scanning Head provide a scanning spot of light that revolves at 59 revolutions per second. The flowing material is moving downward at a rate less than thirty inches per second. Therefore, the spot of light will illuminate every grain, provided the height of the "light spot" is greater than about 0.6 of an inch.

Light reflected from grains of product is collected by the Viewing System which consists of a Lens and Mirror arrangement as shown in (Fig. 14). The Viewing Aperture is in the form of a narrow slit arranged so that a virtual image of this slit is formed coincident with the illumination spot on the stream of flowing product. This slit turns with the Scanning Head and is, therefore, always vertical. Below the slit is a lens, arranged so as to transmit the light with maximum efficiency down to the stationary Photomultiplier Box. (Fig. 3, 10, 11)

The light enters the Photo-multiplier Box and is intercepted by a Beam Splitting Mirror (Fig. 4-14). Part of this light is transmitted through a colored Light Filter (No.1) to Photo-multiplier No.1. Part of the light is also transmitted through Filter (No.2) to Photo-multiplier No.2. Each of these Photo-multipliers provides an electrical output signal proportional to the total light intensity received by that Photo-multiplier Tube. In case the Viewing System is aligned to an area where there is no grain, this System looks up into a black background. This background provides for a minimum of illumination. For all practical purposes, the Photo-multipliers receive a negligible light signal when no product is in view.

Discrimination of defective product is based on color rather than reflected light sensitivity. Since Filter No.1 transmits a different color than Filter No.2, the outputs of Photo-multiplier No.1 and No.2 are proportional to the intensity of colored light transmitted by Filter No.1 and Filter No.2 respectively.

By properly adjusting the relative amplification of the two Photo-multiplier Tubes, the System can be adjusted so that a positive difference signal out of the Difference Amplifier indicates a defective grain while a negative signal indicates a good grain. The (Pulse Generator) is designed to generate a Trigger whenever a positive signal is received. This Trigger causes a high voltage pulse to be applied to the Commutator Slip Ring (Fig. 4-6). This Slip Ring is electrically connected to a single Needle that turns with the Main Rotor. The Commutator is a non-contacting type, using high voltage to bridge the gap between the Rotating Needle and one of the 198 stationary Commutator segments. When a high voltage pulse is received at the Commutator Slip Ring, a very weak spark occurs across the gap to only one of the stationary segments. Each segment is tied to the Trigger Electrode of one of the 198 Cold Cathode Trigger Tubes (Fig. 2). If a Trigger Tube receives a Trigger, it is turned on and current flows through the Solenoid of one of the Reject Valves (Fig. 7). This Valve opens and a short blast of air blows the defective product across the dividing partition of the Collection Hoppers.

The transmission of the reflected light, generation of a Trigger and application of the voltage to a particular Trigger Tube takes place in a very short time (a few millionths of a second). The actuation of the Reject Valve and air blast takes about 14 milliseconds for one cycle. This means that the Valve is open for slightly less than one revolution of the Scanning Head. Because of the Valve inertia, it is necessary to apply power to the Valve for approximately 11 milliseconds duration.

It is characteristic of gas Trigger Tubes that they may be turned on with a Trigger Electrode, but they can be turned off only by interrupting the flow of the plate current. In the present Machine the Trigger Tubes are arranged on six chassis in twelve groups. Plate power, 190 volts, is applied to each group through a Switch that opens once each revolution of the Scanning Head. The timing of this Switch is adjusted so the Switch opens and recloses just before the light and Viewing System is aligned with that particular bank of Tubes. In this way, any given group of Tubes has plate power, applied when a Trigger is received and the plate power remains applied until approximately 11 milliseconds after the Trigger Tube has been turned on.

ELECTRONIC SORTER

ROTOSCAN

The Plate Circuit Commutator (Fig. 11) with twelve Switches, one for each bank of Tubes, is located on the Shaft of the Rotor Drive Motor which turns at 1770 revolutions per minute. A double Lobe Cam is used to actuate the Switches so that the Switches operate at the scanning head rate of 3540 revolutions per minute. The Motor and Scanning Head Rotor are connected by a Gilmer Timing Belt (Fig. 11) so that there will be no relative shift in angular position of the Rotor with respect to the Cam.

Summary of operation

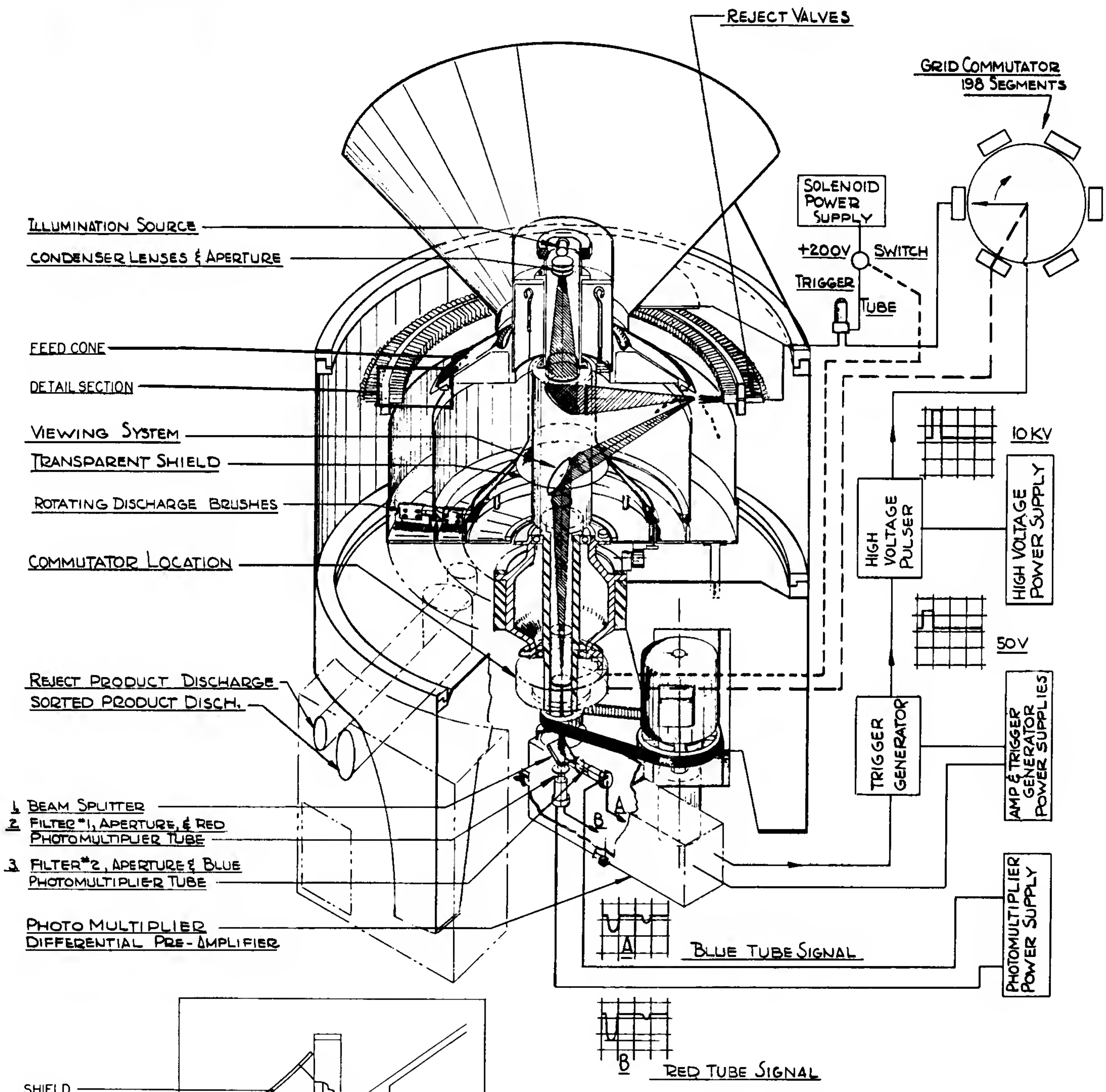
A summary of the Machine operation is as follows: A defective grain causes a signal to be generated that is applied as a high voltage pulse to the Slip Ring of the 198 Commutator. This signal is transmitted to the Trigger Electrode of one of the 198 Trigger Tubes. When a Trigger Tube fires, it causes its associated Reject Valve to open and a blast of air blows the grain over the dividing partition. The time for the occurance of this blast of air is approximately 14 milliseconds; the reflected light transmission and signal generation occurs in only a few millionths of a second.

Courtesy of FMC Corporation.

Exhibit 1. Sorter Operation.

ELECTRONIC SORTER

ROTOSCAN



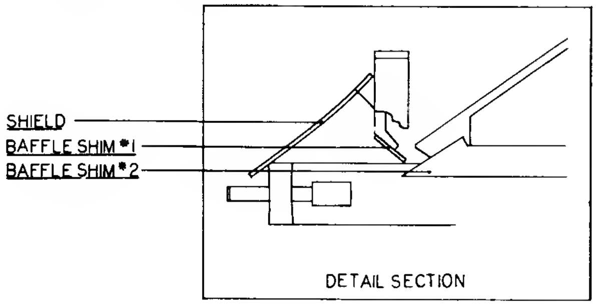
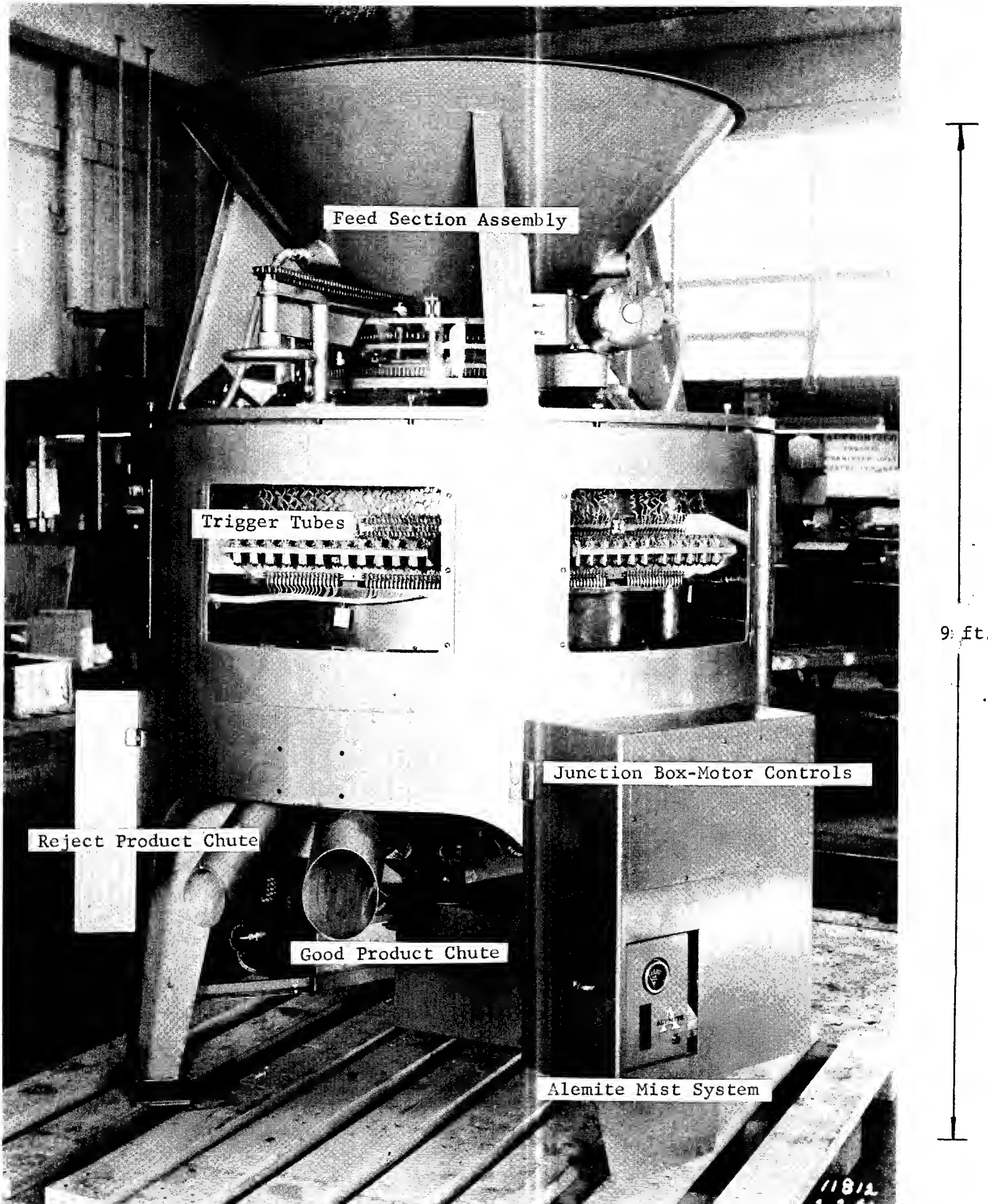
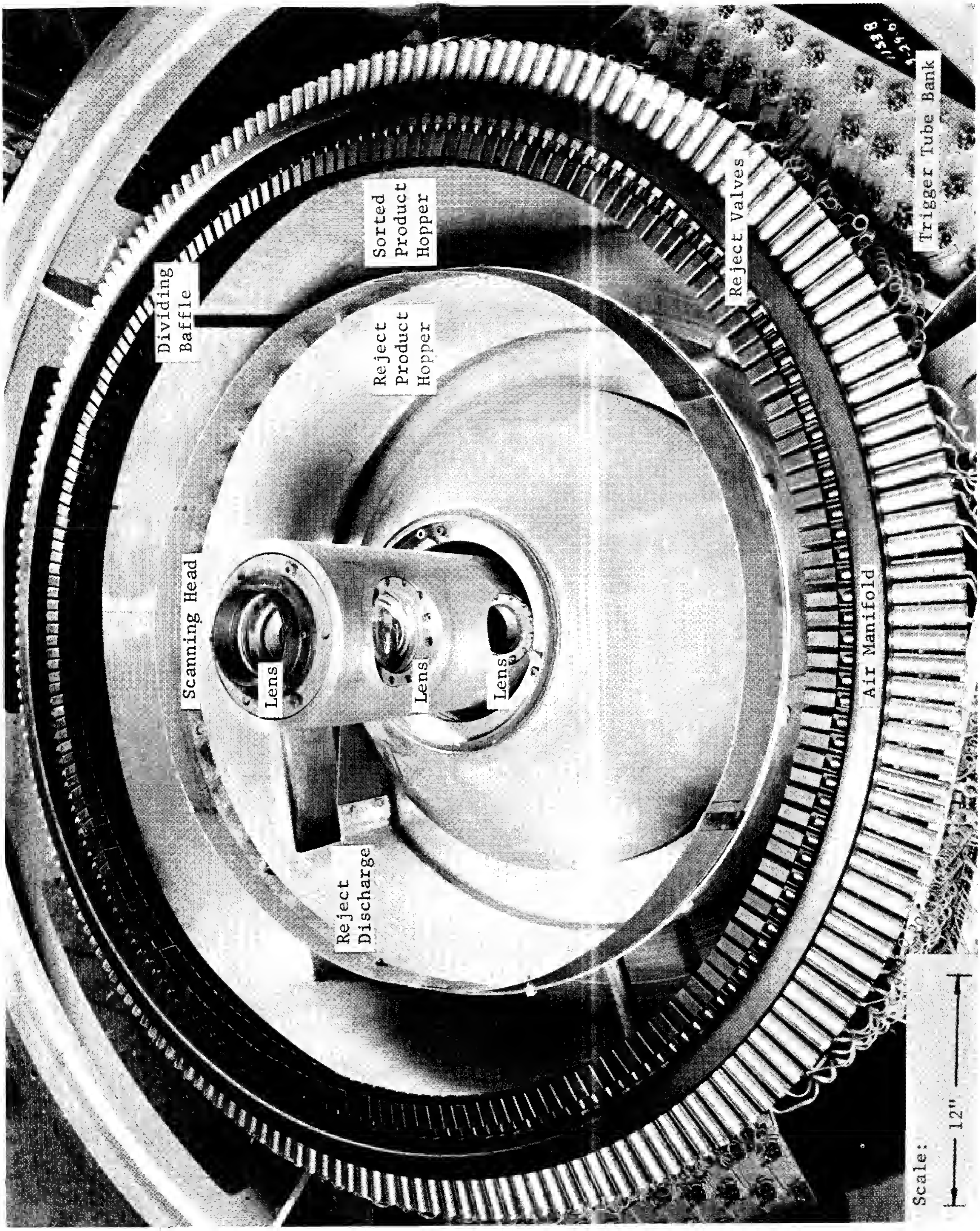


FIG 14



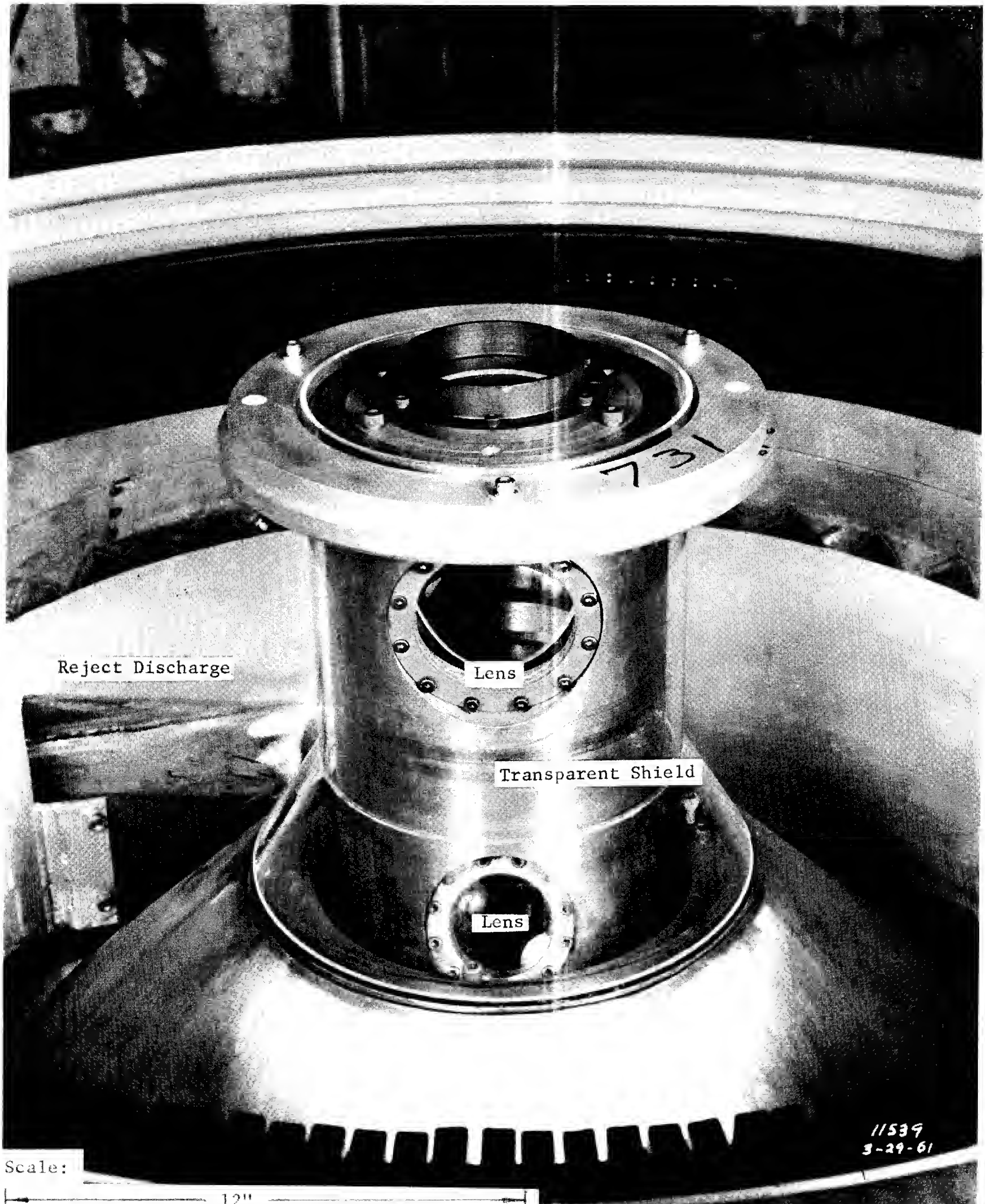
Courtesy of FMC Corporation

Exhibit 1. Sorter Operation



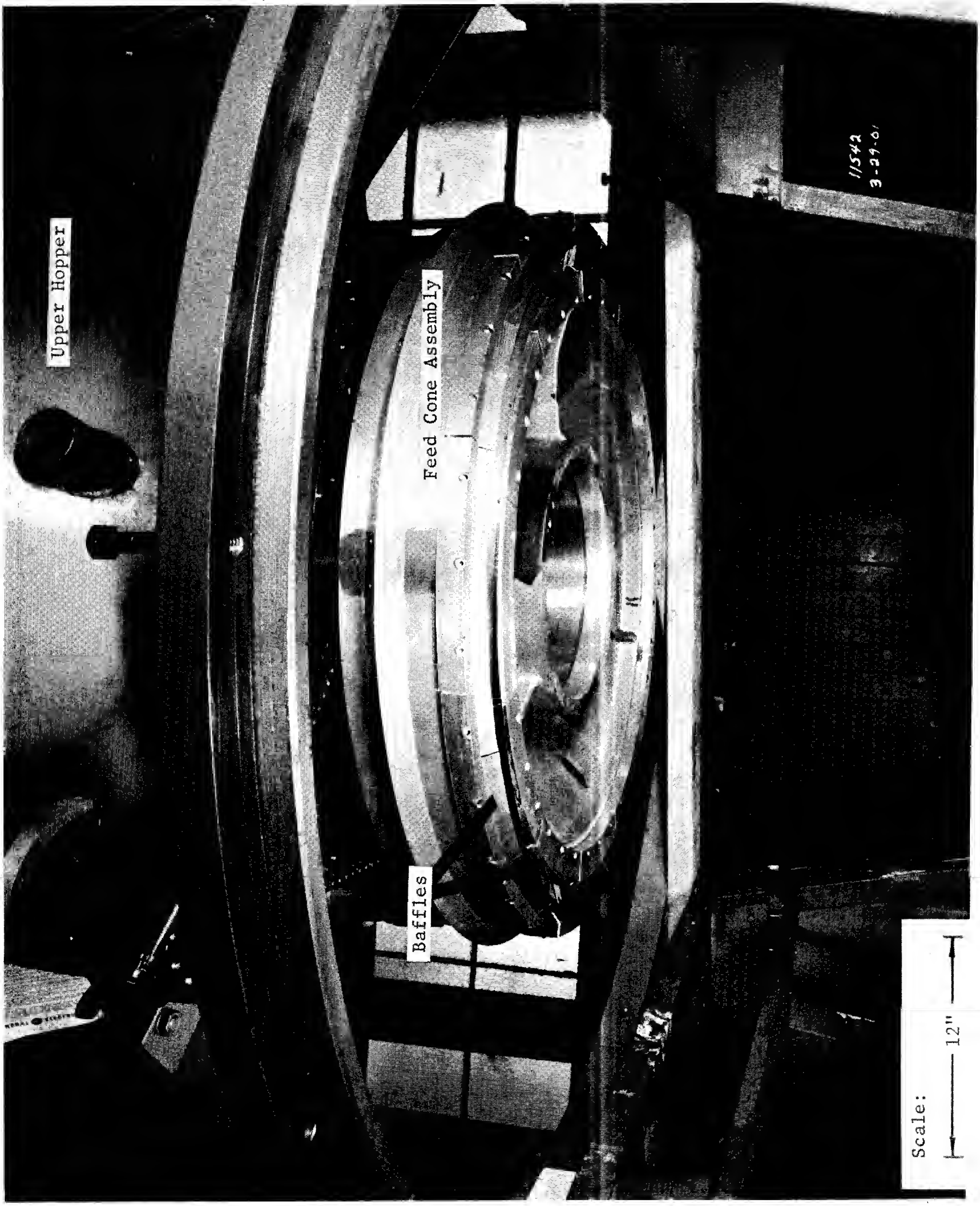
Courtesy of FMC Corporation

Exhibit 1. Sorter Operation



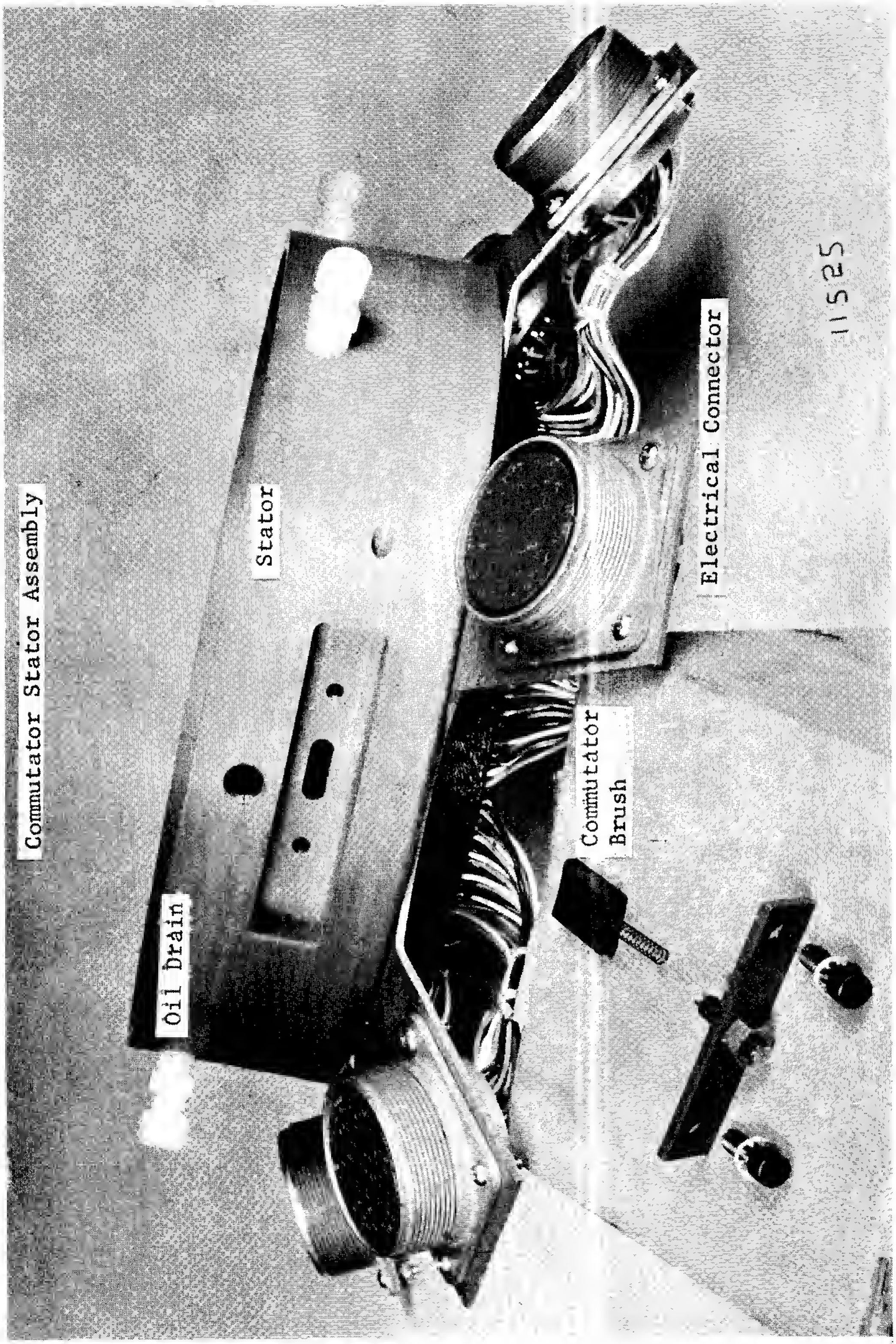
Courtesy of FMC Corporation

Exhibit 1. Sorter Operation



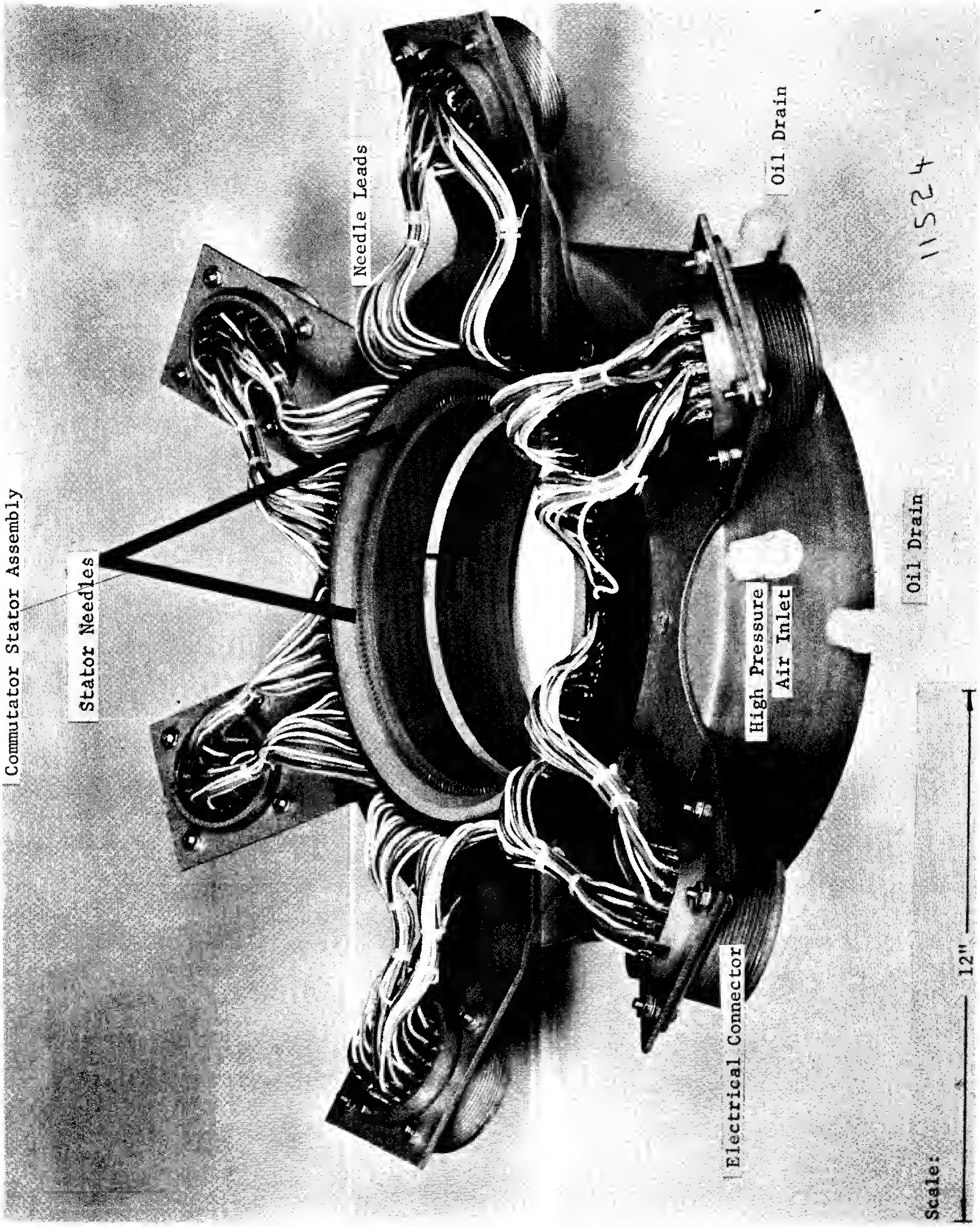
Courtesy of FMC Corporation

Courtesy of FMC Corporation



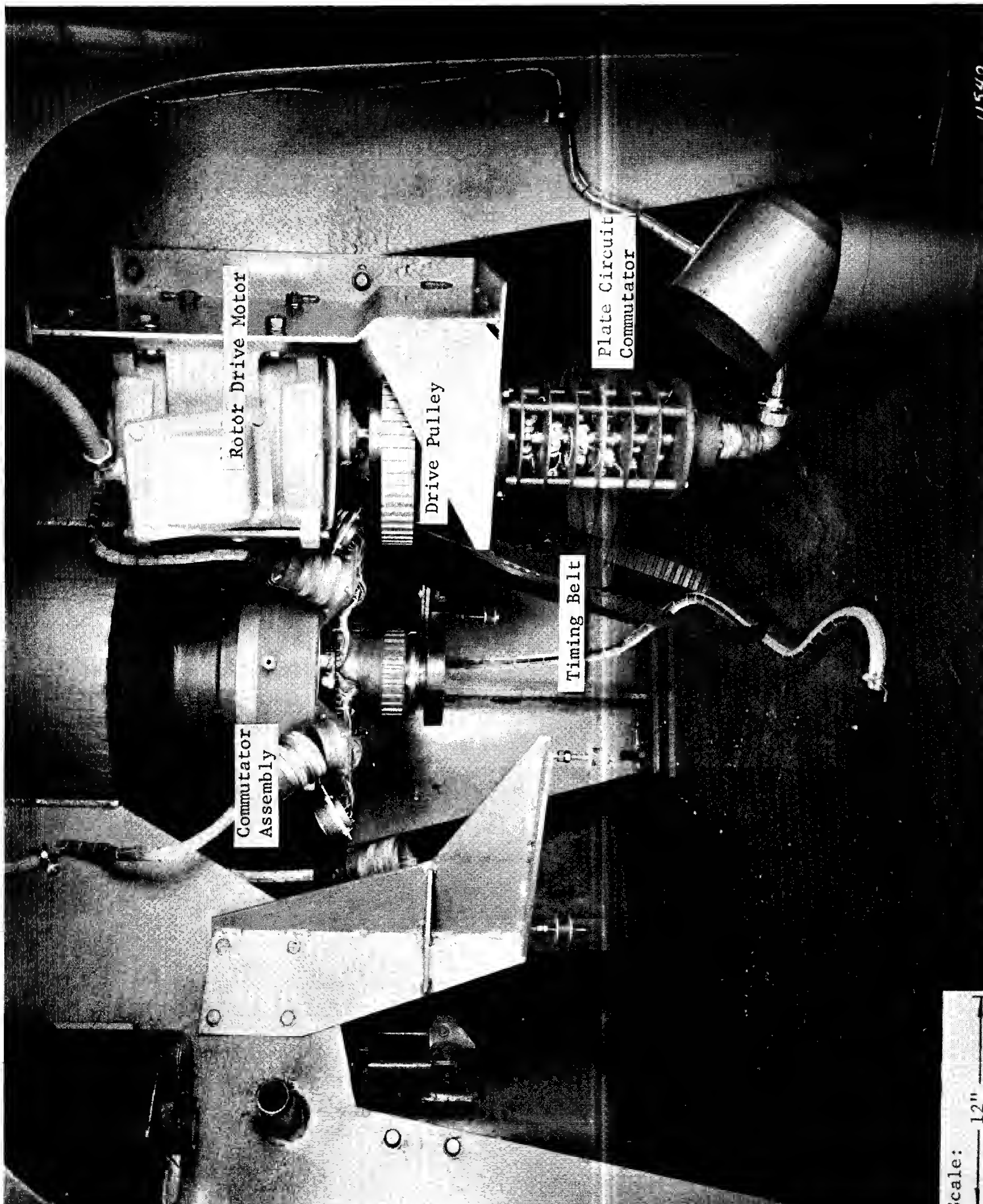
Scale: 12"

Courtesy of FMC Corporation



Courtesy of FMC Corporation

Exhibit 1. Sorter Operation



Courtesy of FMC Corporation

CANNING MACHINERY DIVISION
FMC CORPORATION
San Jose, California

INTER-OFFICE MEMORANDUM

DATE: September 23, 1963

FROM: D. W. Chamberlin

TO: S. H. Creed

AT: San Jose

H.L. Link
John Boyce
Rte: R.G.Beverly
R.E.Herald
W.M.Myers
Rte: T.E.Roberts
B.M.Carney
Rte: M.Steadman
W.Keen
Rte: R.B.Leslie
S.B.Tetreault
H.W.Adams
CEL
CEL

SUBJECT: ROTOSCAN, UNCLE BEN'S RICE, INC.
(Ref. Letter Station to Herald, Aug. 30, 1963)

The accompanying log sheets indicate the problems encountered during last week's trip to Consolidated in Houston, Texas with Bill Carney and Bill Myers. The visit was very timely and well forecast by Bill Myers' previous discussion with the customer.

Three of the four machines at this installation have been in operation for only about nine weeks and have given a great amount of mechanical trouble. The starter heater "kick-out" was attributed to some faulty heaters rather than high console temperatures. The "hanging-on" of trigger tubes had mostly cleared up before FMC's arrival. This phase will be reported by Bill Carney.

There has been a correlation of tube "hang-on" and plate breaker assembly bearing failure. It was found that insufficient clearance was given between the flexible coupling halves, thereby preloading the bearings when the assembly was bolted in place. Two sets of bearings were replaced before this was found. It is asserted that this bearing failure loading caused random changes in timing of the plate current cycle with respect to the trigger tube banks in question due to the flexibility of the coupling causing tubes to "hang-on". (This might not be observed on the oscilloscope with internal triggering.)

A more important problem concerned the use of cam followers to guide the feed and discharge sections. These followers "freeze-up" and cause wear and loud vibration. These have been, or will be, replaced by sealed roller bearings in all places where possible. Additional units must be made and sent to Consolidated.

The problem of greatest concern is the spindle bearing failures evidenced. A total of six failures is recalled, experienced by FMC or the customer. It is believed the last failure observed was primarily due to assembly practice and parts handling and somewhat to parts design. Mechanical design and tolerances of future machines has been improved in these bearing areas, but it is strongly recommended that these high speed bearings <u>not</u> be handled by our general assembly department.

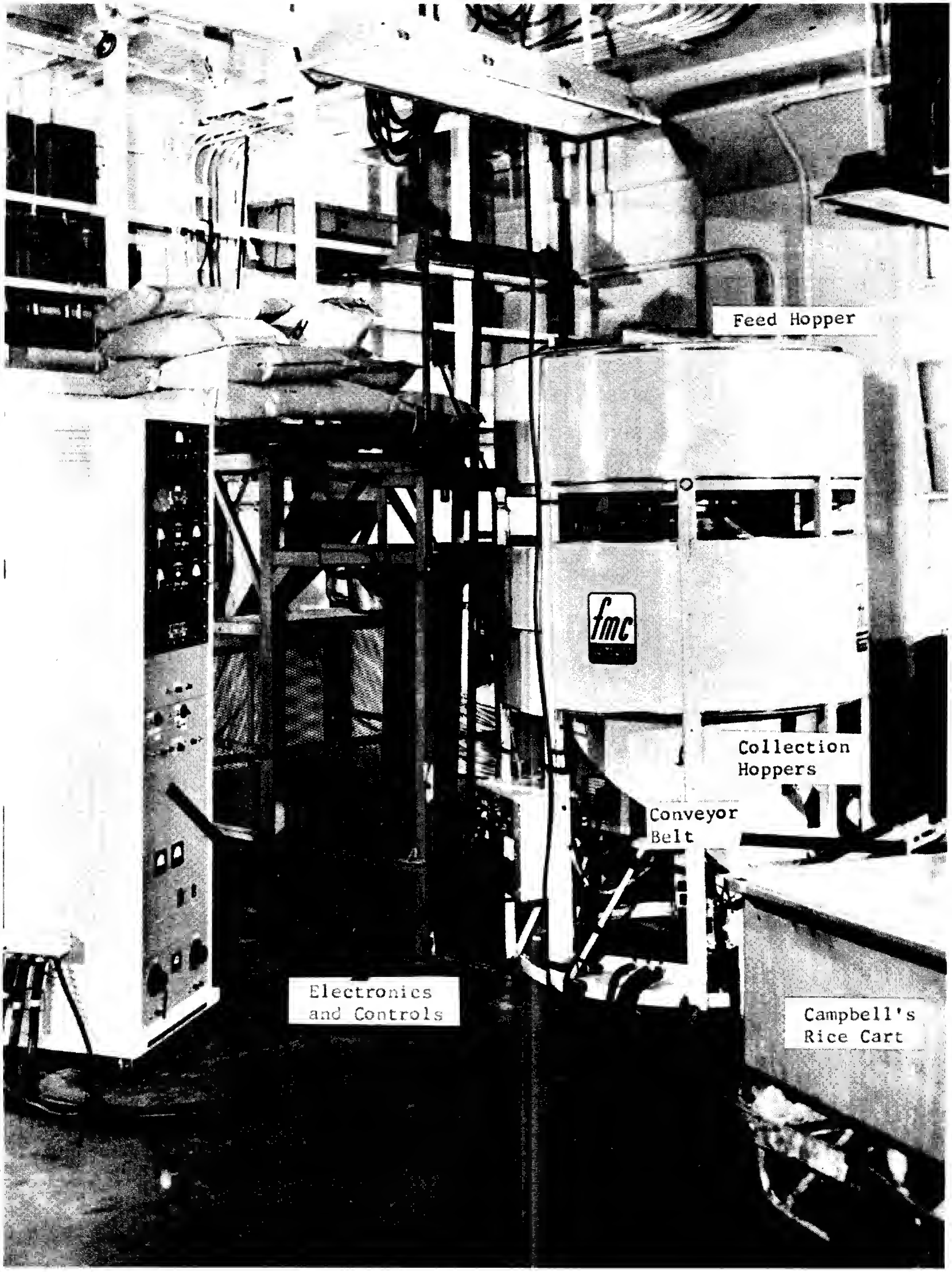
The oil mist lubrication has always been a problem in determining the oil flow necessary for the bearings without detrimental effect of excessive oil to the stator assembly. Some experimentation was made with an oil line to the upper bearing only, hoping to find a more efficient oil delivery system.

Admittedly, much confusion existed in assembling the last machines due to lack of engineering assembly drawings, lists, and experience; however, much drafting time has been spent in making organized sub-assembly breakdown, function improvement and ease of assembly and corrections of drawings.

It is contended then that with more concentration available on assembly workmanship, the future machines can be made much more reliable with the improved design as it exists. However, further investigation into the spindle bearing failure will have to be made by analyzing failed bearings and submitting drawings to the bearing people for application approval.

D. W. Chamberlin : jc

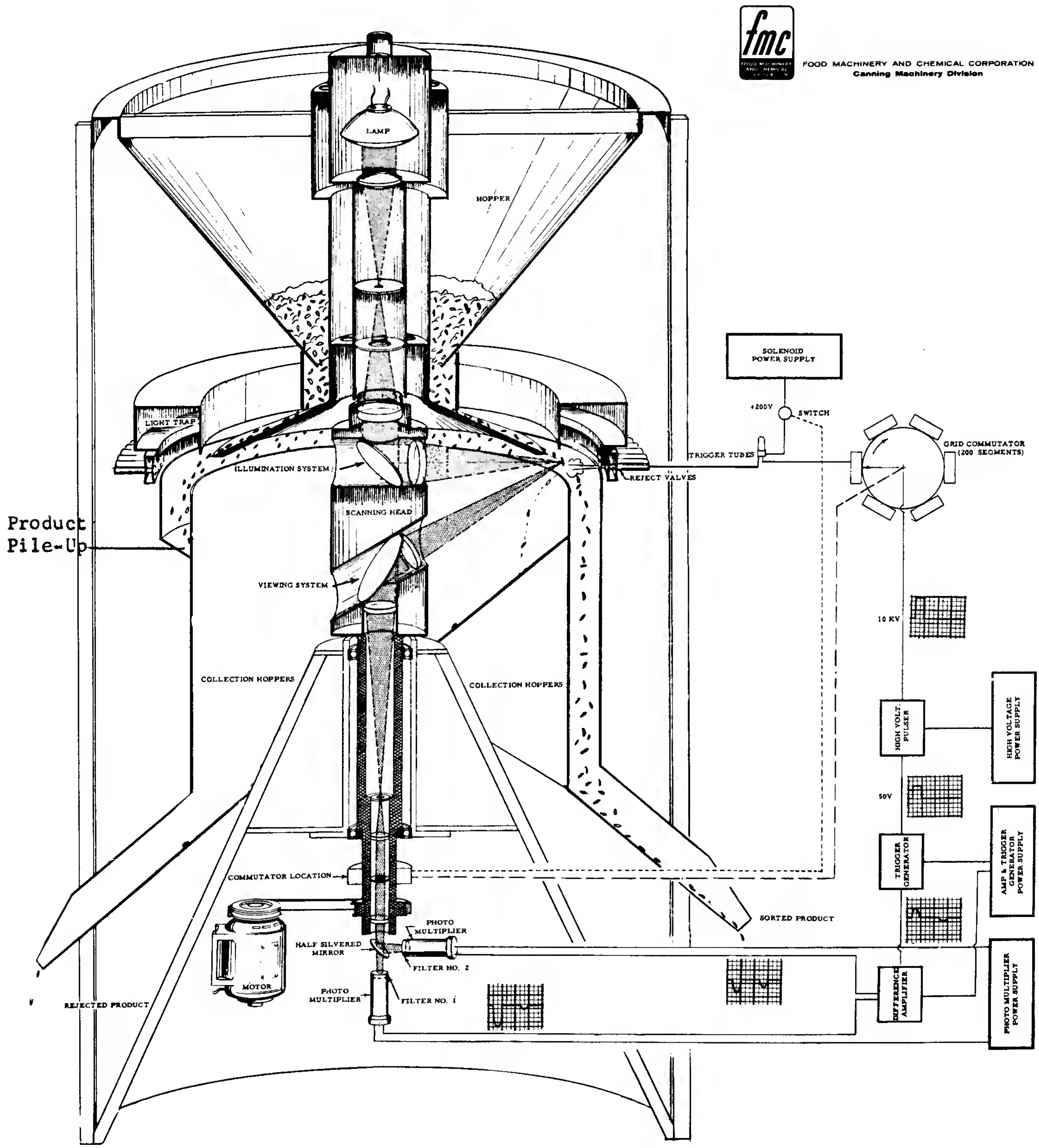
Exhibit 3. Development Model Sorter.



Courtesy of FMC Corporation

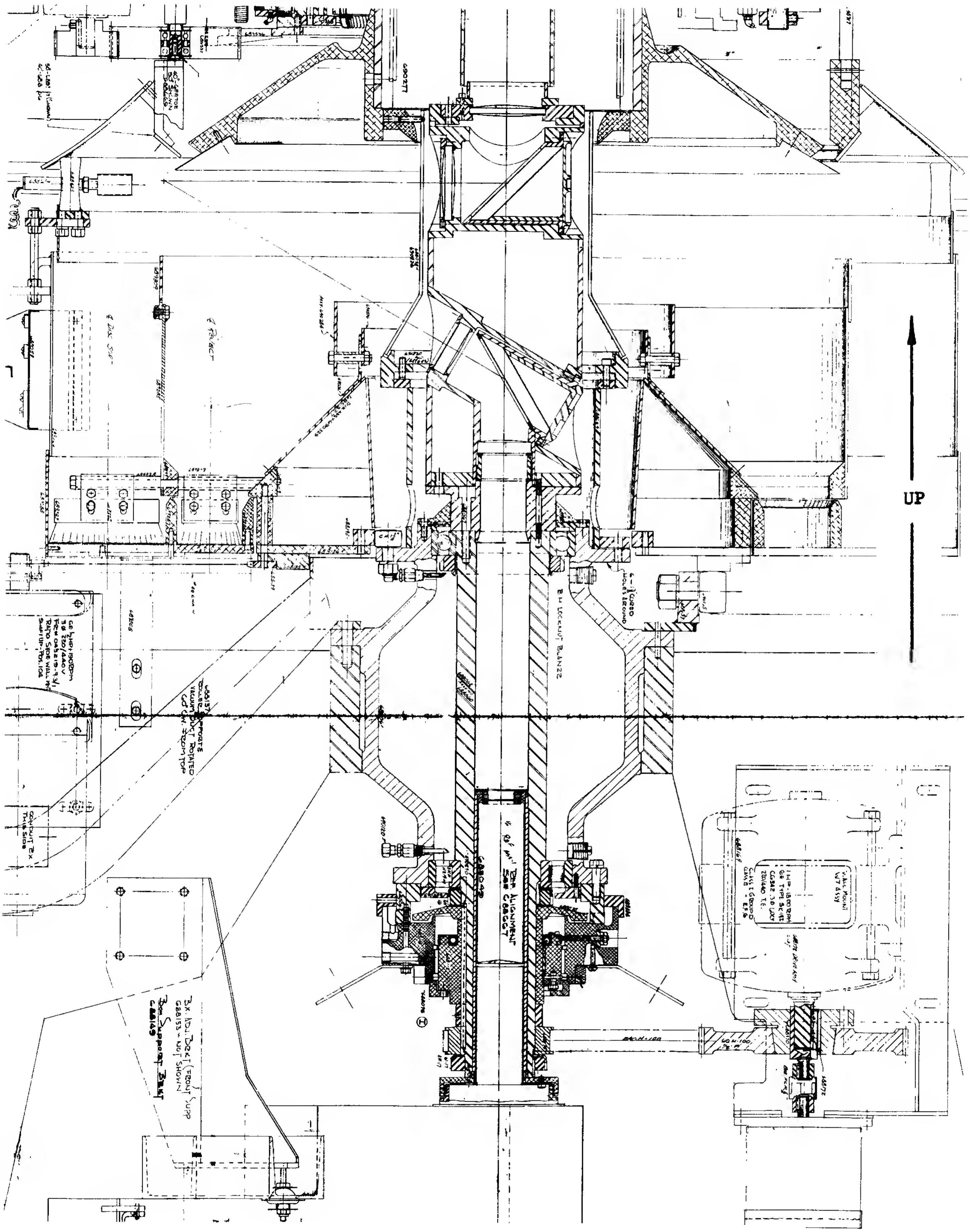
Exhibit 3. Development Model Sorter

ROTOSCAN GRAIN SEPARATOR

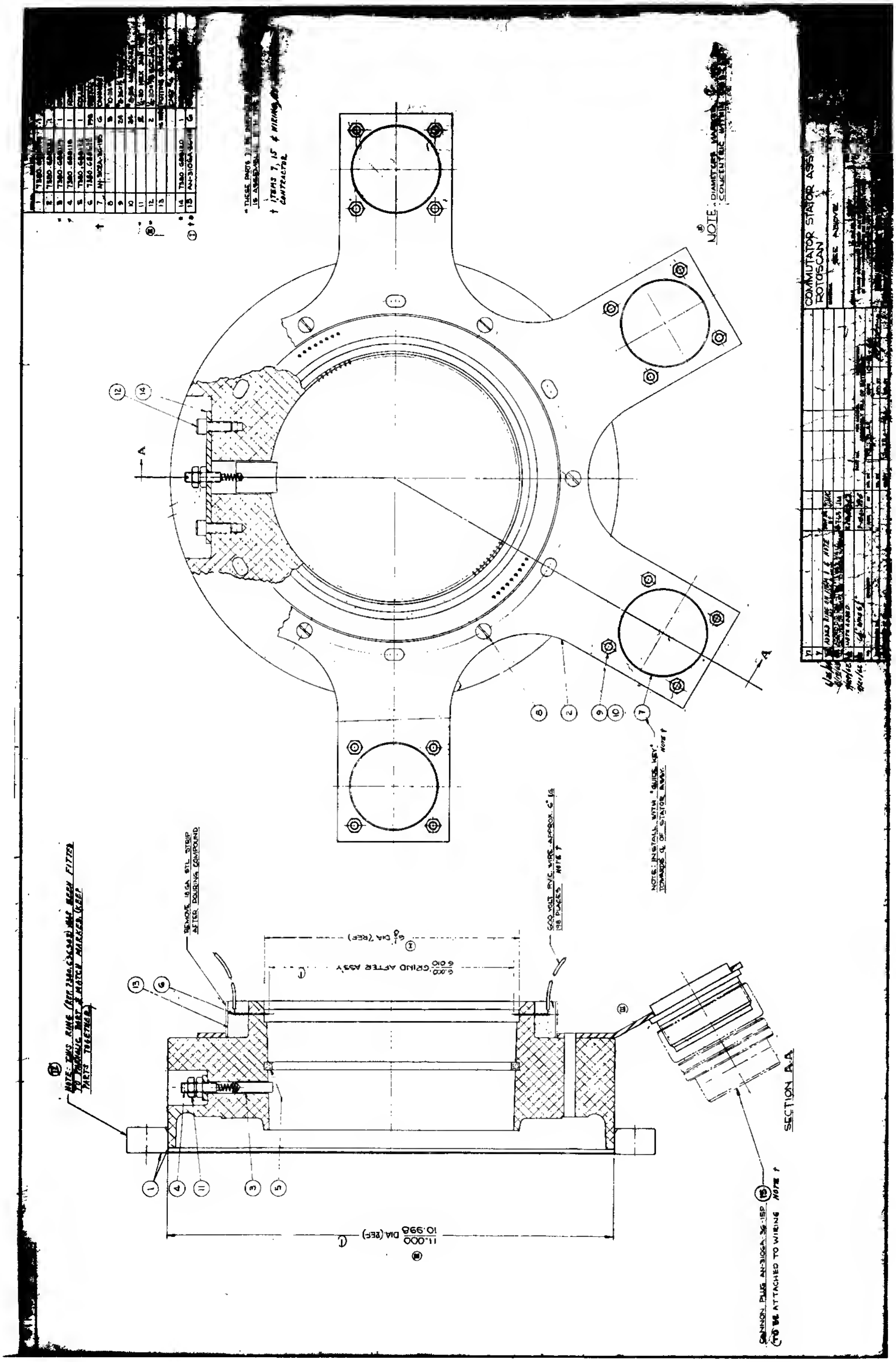


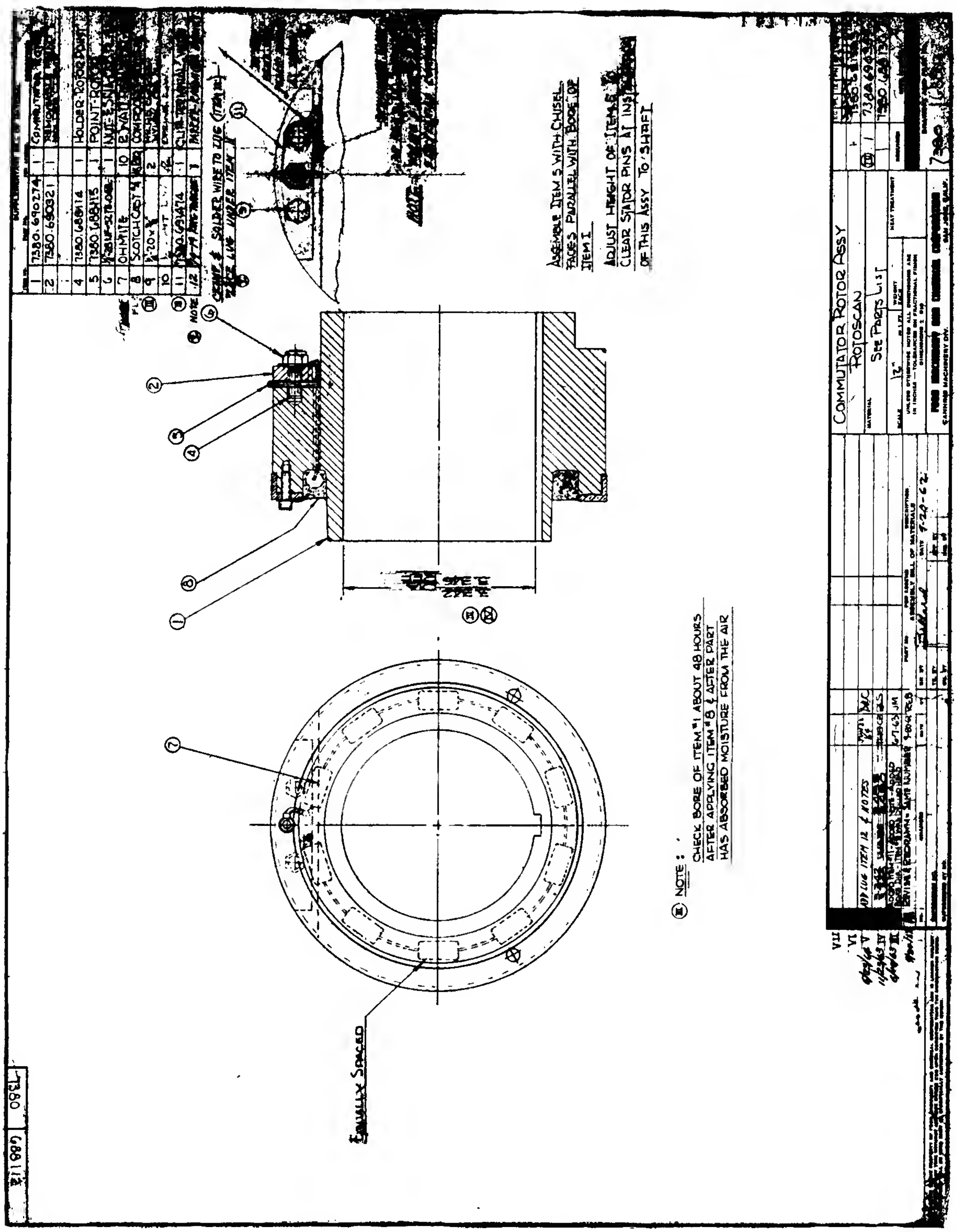
Courtesy of FMC Corporation

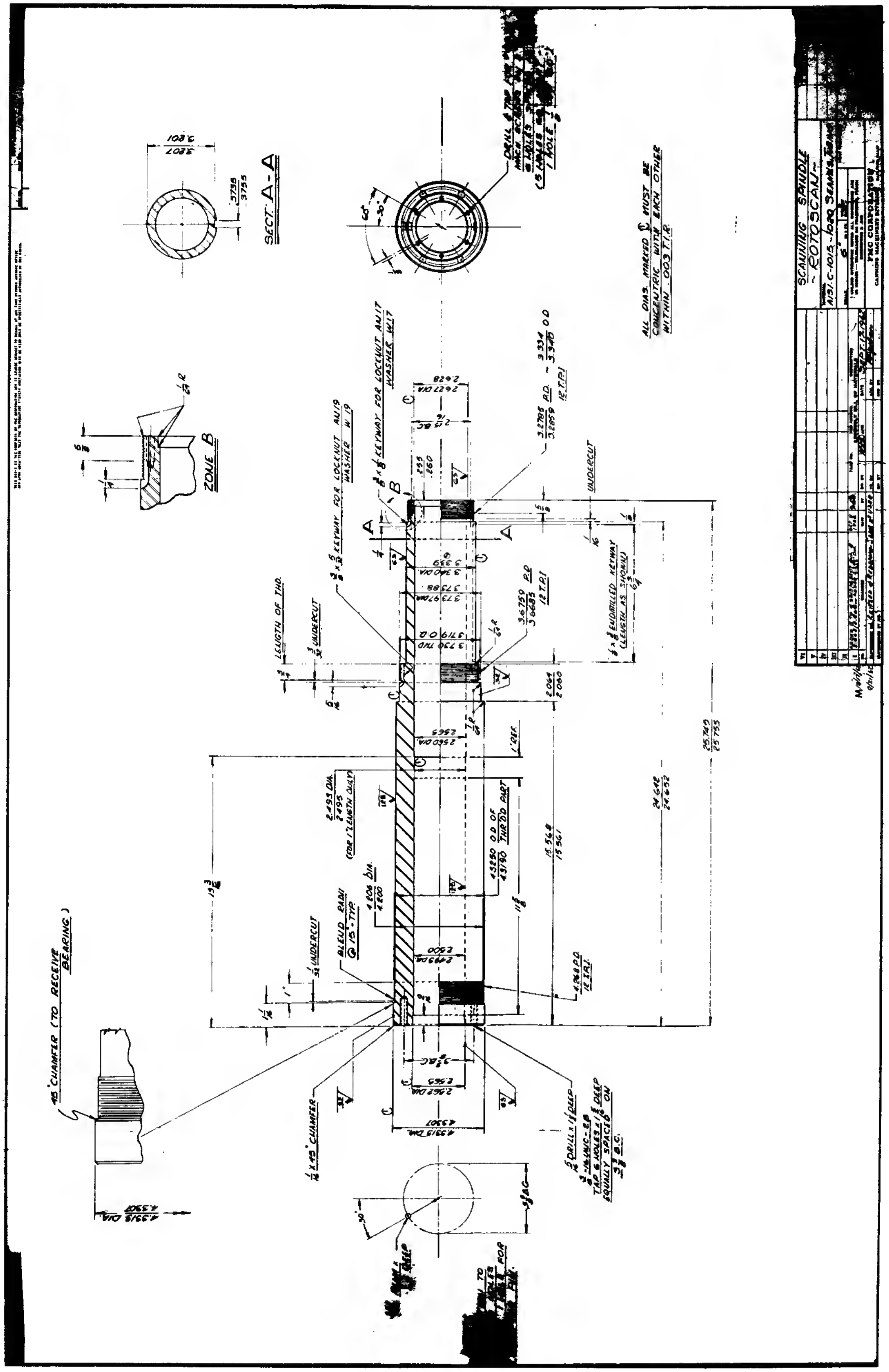
Exhibit 4. Sorter Assembly



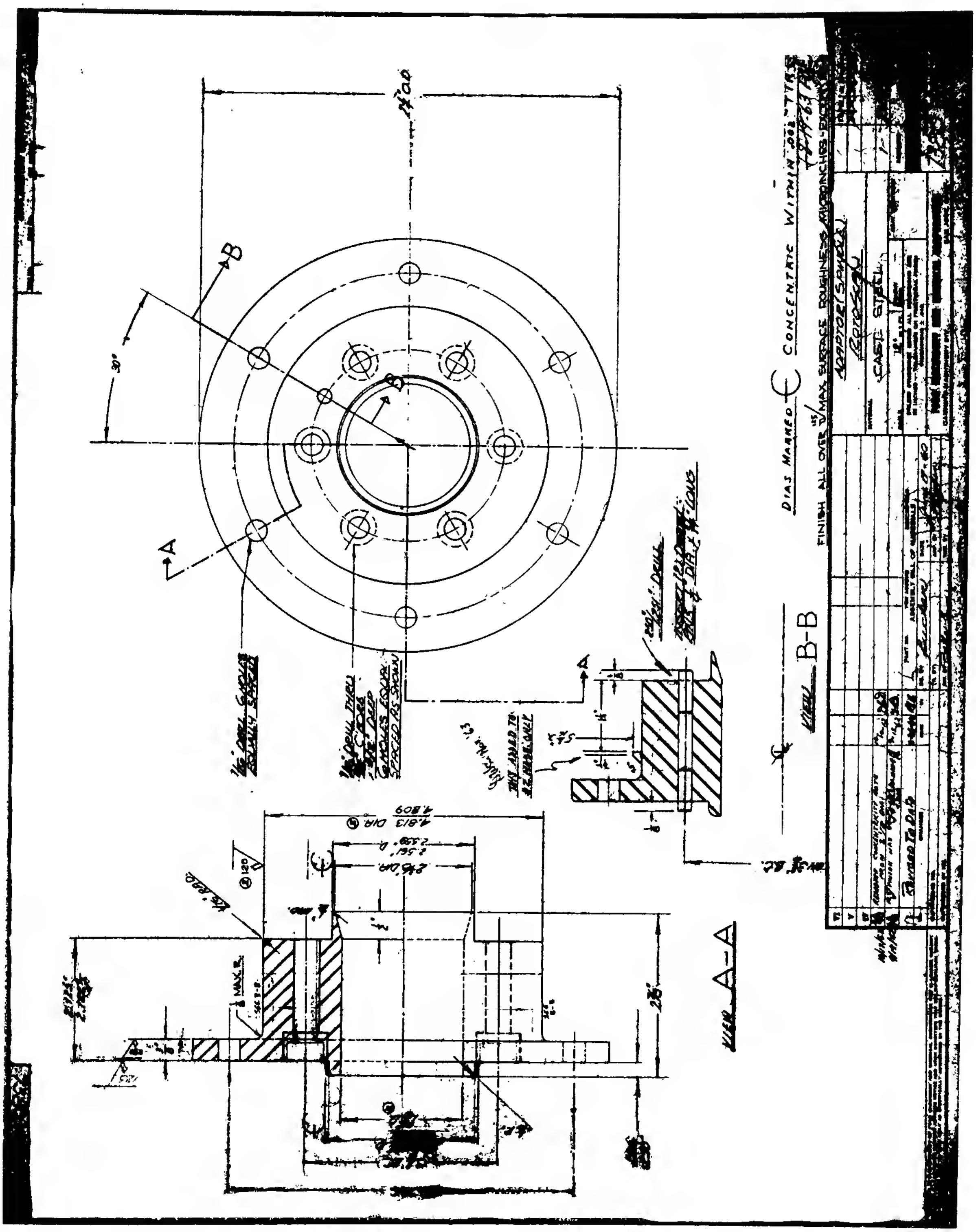
Courtesy of FMC Corporation



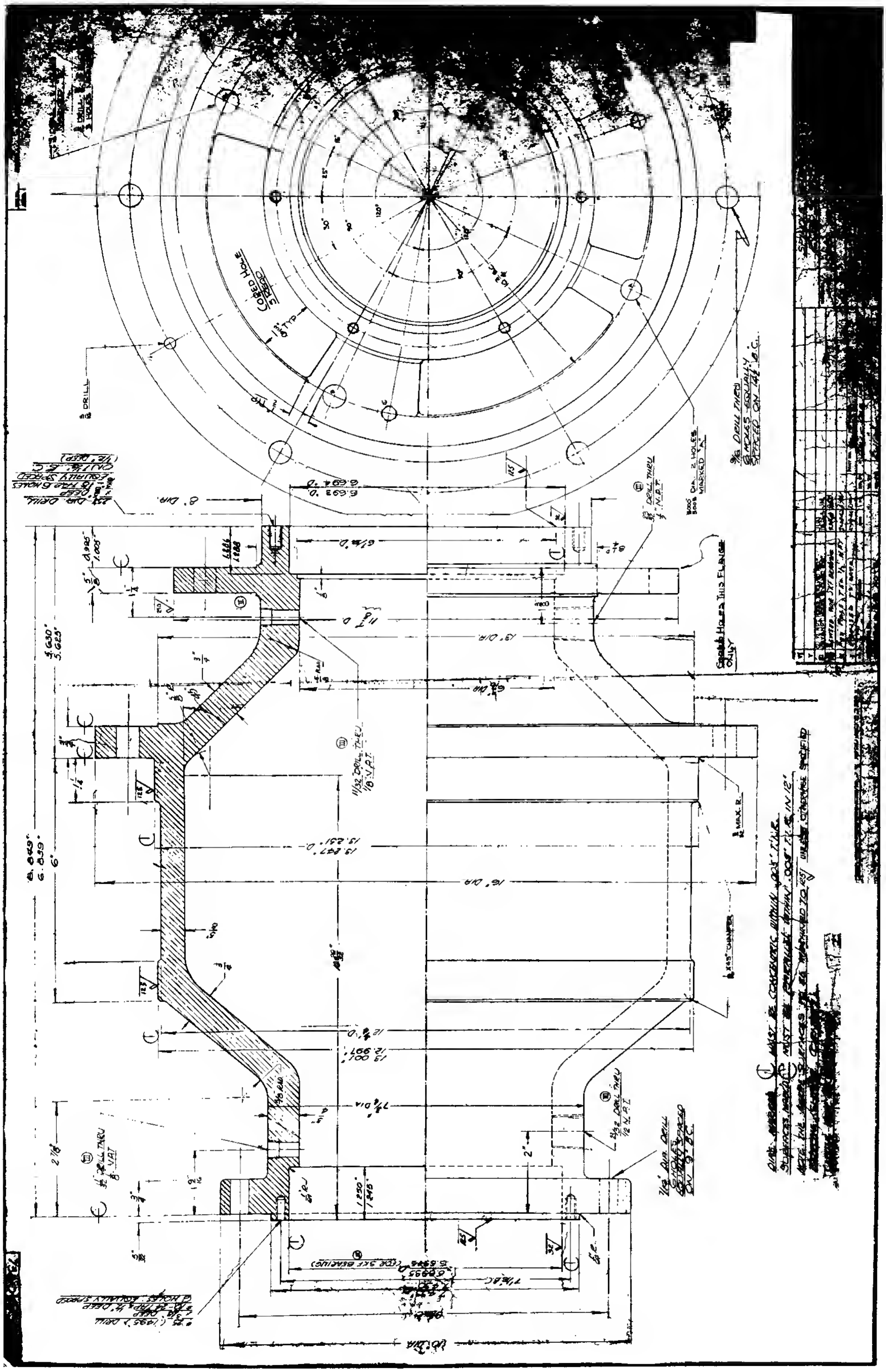




Courtesy of FMC Corporation

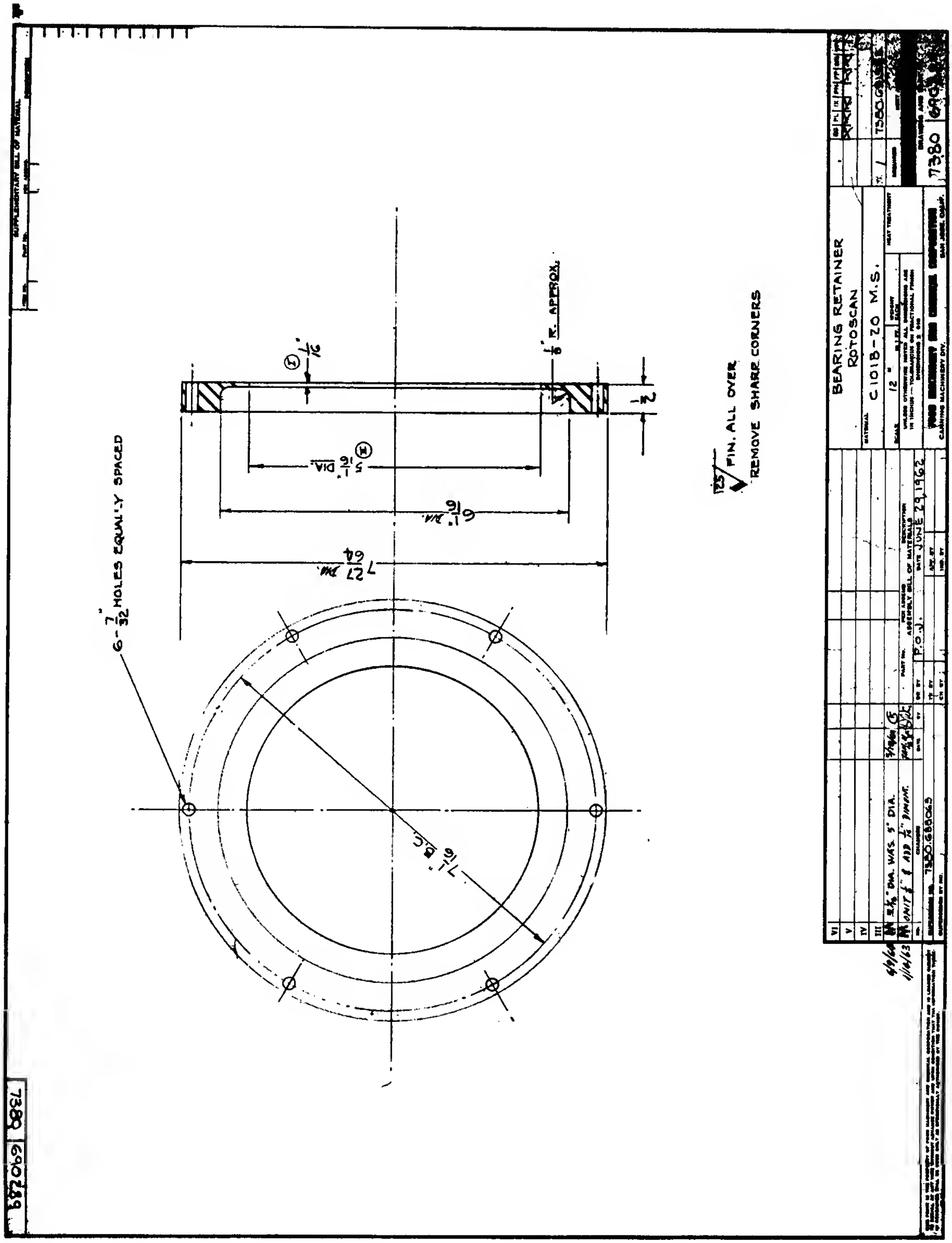


Courtesy of FMC Corporation

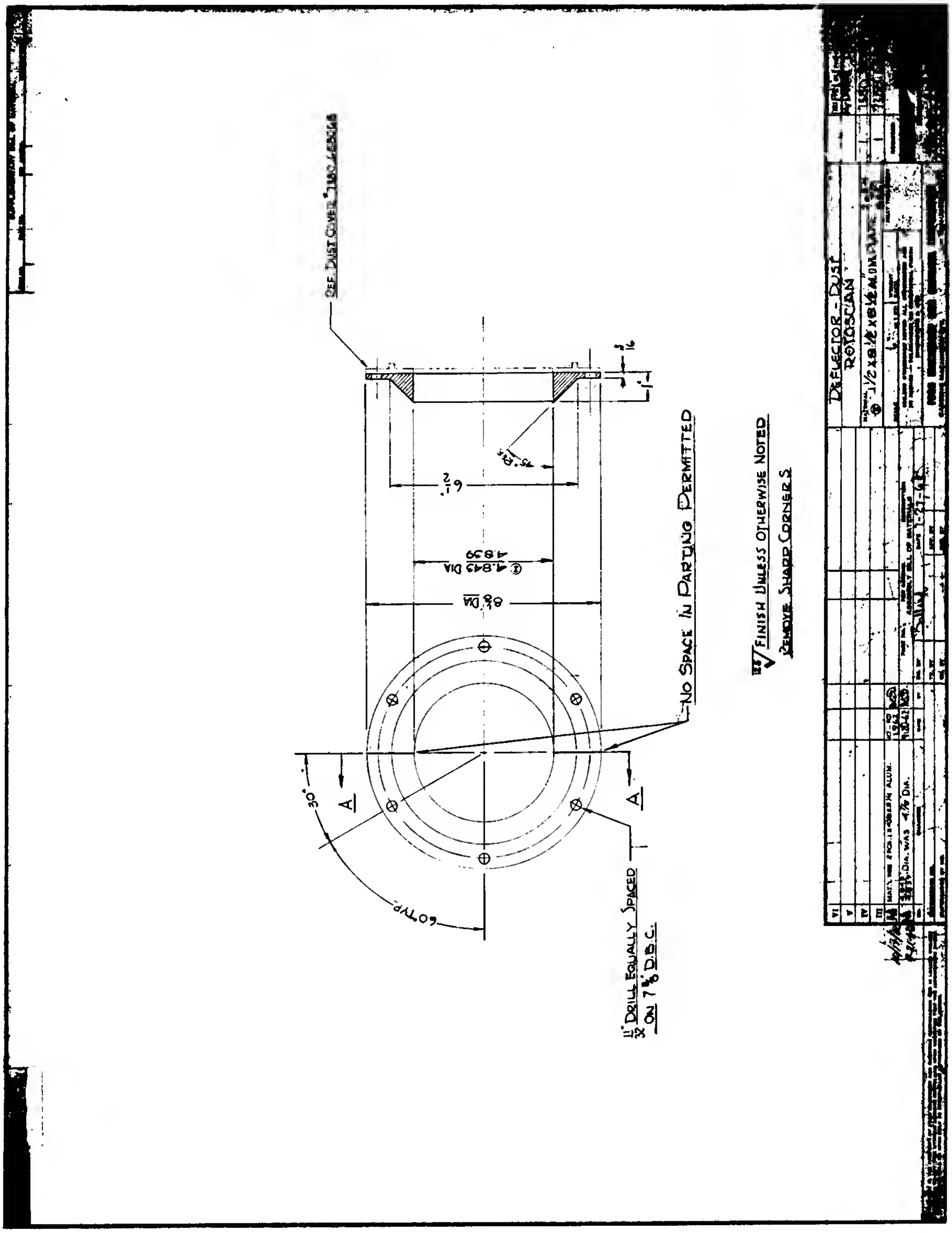


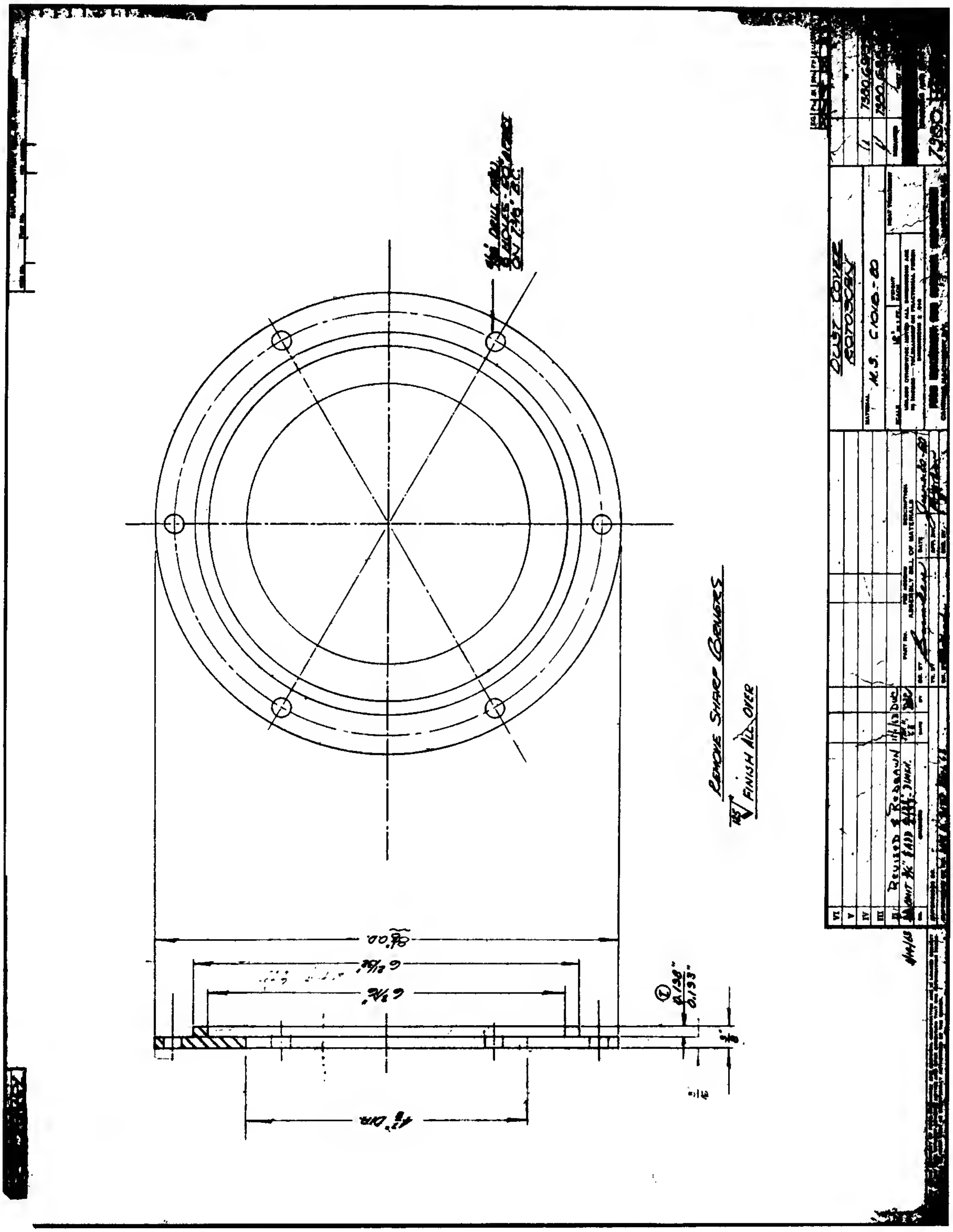
Spindle Housing-Rotoscan

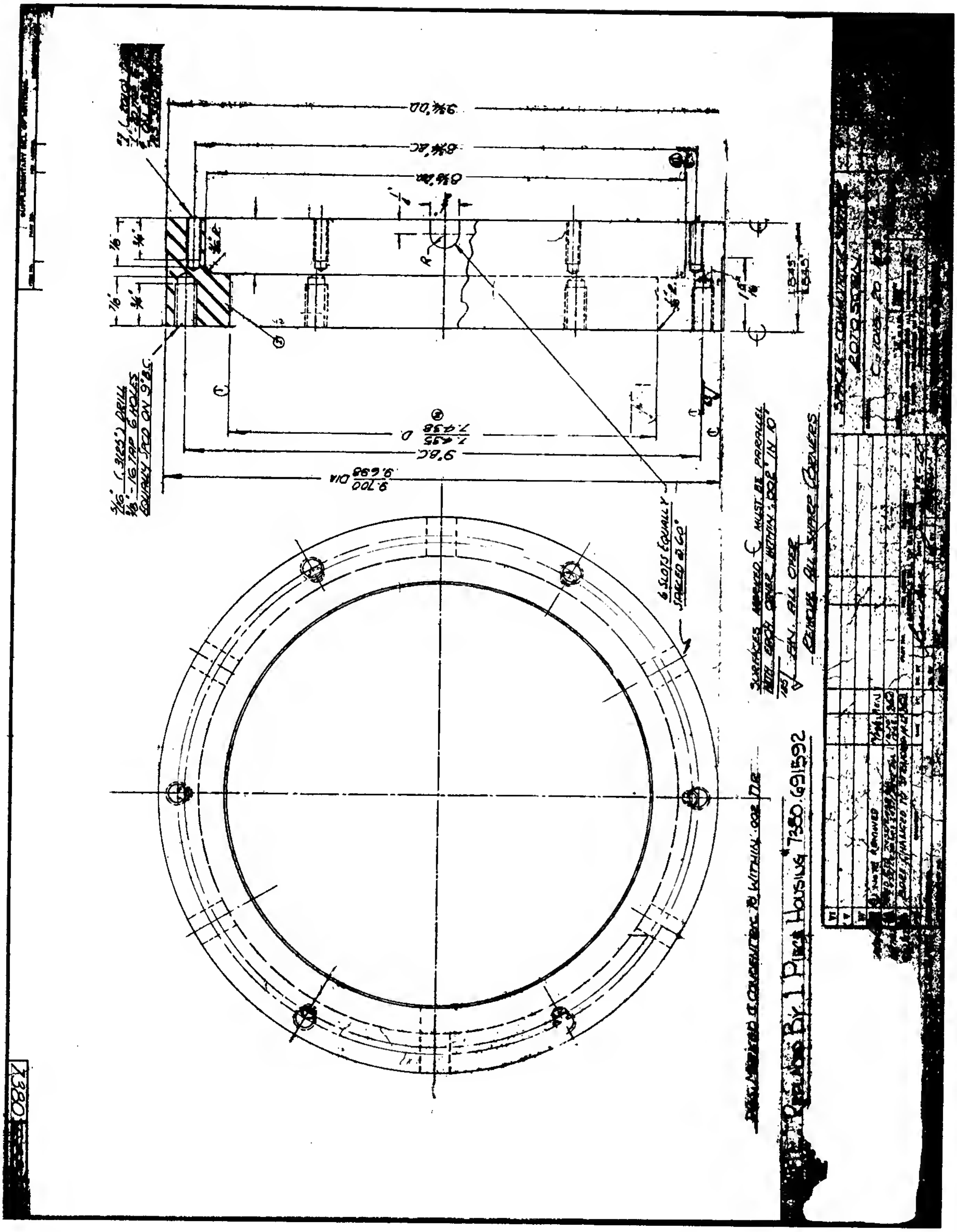
Courtesy of FMC Corporation



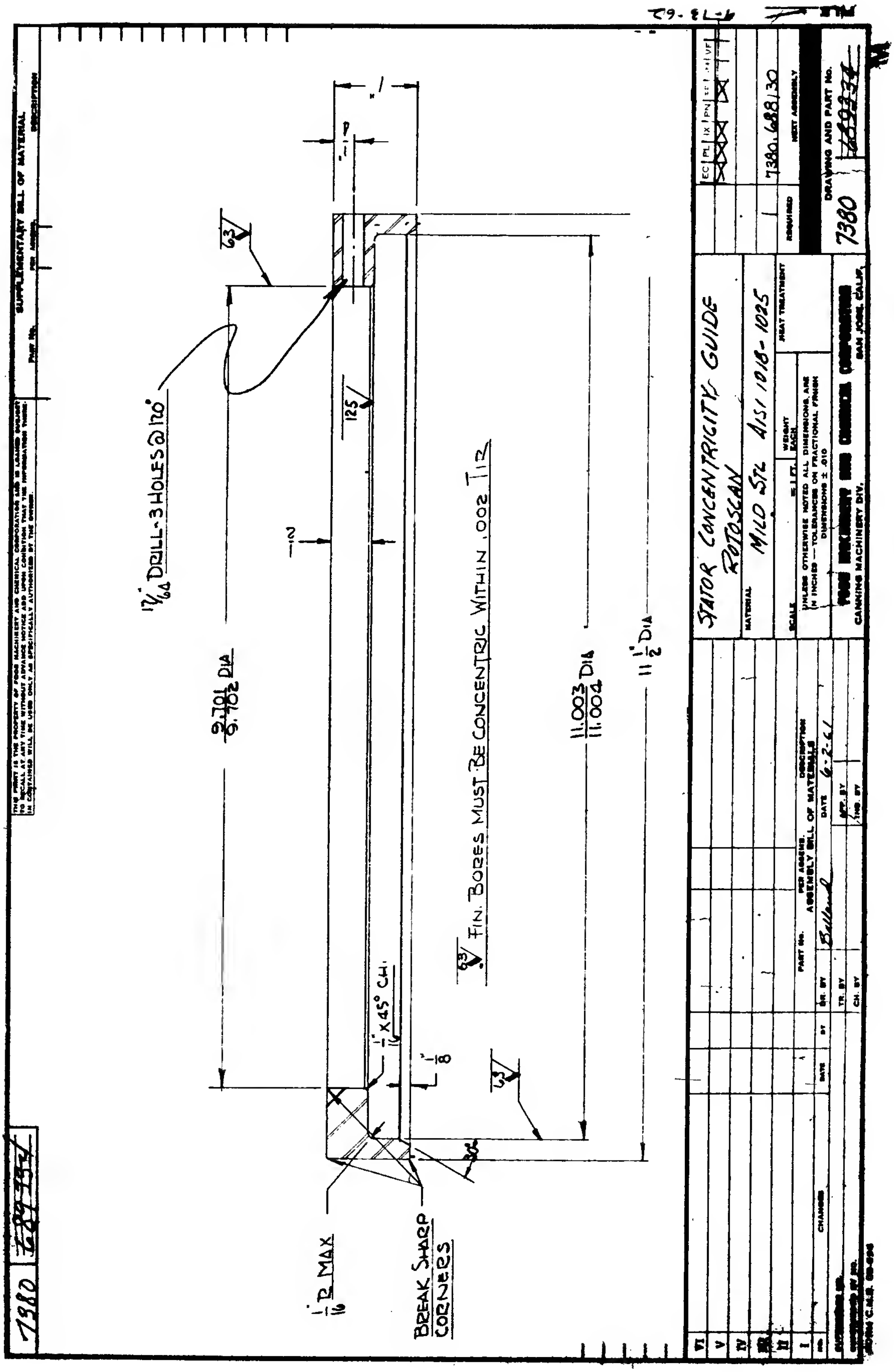
Courtesy of FMC Corporation


DEFLECTOR - DUST
ROTOSCAN
NO SPACE IN PARTING PERMITTED
FINISH UNLESS OTHERWISE NOTED
REMOVE SHARP CORNERS
DRILL EQUALLY SPACED
ON 7⅝ D.B.C.
60° TYP.
30°
4.843 DIA
4.839
8⅞ DIA





Courtesy of FMC Corporation


STATOR CONCENTRICITY GUIDE
ROTOSCAN
MILD STL AISI 1018-1025
FIN. BORES MUST BE CONCENTRIC WITHIN .002 TIR
17/64 DRILL-3 HOLES @ 120°
9.701 / 9.702 DIA
11.003 / 11.004 DIA
11 1/2 DIA
1/16 x 45° CH.
1/16 R MAX
BREAK SHARP CORNERS
7380.688130
7380
CANNING MACHINERY DIV.
SAN JOSE, CALIF.

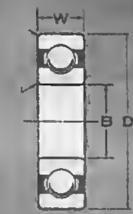
TYPE 3LL00 3L00

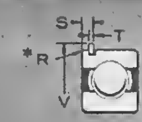
SINGLE ROW RADIAL
* EXTRA-EXTRA-LIGHT AND
EXTRA-LIGHT SERIES

AVAILABLE TYPES AND SIZES — BEARING NUMBERS

open	one shield	two shields	one seal	two seals	shield and seal	snap ring	snap ring and one shield	snap ring and two shields	snap ring and one seal	snap ring and two seals	snap ring shield and seal
3L00	73L00	773L00	Z83L00	Z893L00	Z873L00						
3L01	73L01	773L01	Z93L01	Z993L01	Z973L01						
3LL02	.....	......	......	....	....	.....	......	....	....	....	....
3L02	73L02	773L02	Z83L02	Z993L02	Z973L02	43L02	473L02	4773L02	Z493L02	Z4993L02	Z4873L02
3LL03	.....	......	......	....	....	.....	......	....	....	....	....
3L03	73L03	773L03	Z83L03	Z993L03	Z973L03	43L03	473L03	4773L03	Z493L03	Z4993L03	Z4973L03
3LL04	.....	......	......	....	....	.....	......	....	....	....	....
3L04	73L04	773L04	Z93L04	Z993L04	Z973L04	43L04	473L04	4773L04	Z493L04	Z4993L04	Z4973L04
3LL05	.....	......	......	....	....	.....	......	....	....	....	....
3L05	73L05	773L05	Z93L05	Z893L05	Z973L05	43L05	473L05	4773L05	Z493L05	Z4993L05	Z4973L05
3L06	73L06	773L08	Z93L08	Z993L06	Z873L06	43L09	473L08	4773L08	Z483L08	Z4993L08	Z4973L08
3L07	73L07	773L07	Z83L07	Z983L07	Z973L07	43L07	473L07	4773L07	Z493L07	Z4983L07	Z4973L07
3LL08	.....	......	......	....	....	.....	......	....	....	....	....
3L08	73L08	773L08	Z93L09	Z893L08	Z973L08	43L08	473L08	4773L08	Z493L08	Z4993L08	Z4973L08
3L09	73L09	773L08	Z93L09	Z993L09	Z973L09	43L09	★473L09	★4773L08	Z483L09	Z4983L09	Z4973L09
3L10	73L10	773L10	Z93L10	Z993L10	Z873L10	43L10	473L10	4773L10	Z493L10	Z4993L10	Z4973L10
3L11	73L11	773L11	Z93L11	Z993L11	Z973L11	43L11	★473L11	4773L11	Z493L11	Z4993L11	Z4973L11
3LL12	.....	......	......	....	....	.....	......	....	....	....	★........
3L12	73L12	773L12	Z93L12	Z993L12	Z973L12	43L12	473L12	4773L12	Z493L12	Z4993L12	Z4973L12
3L13	73L13	773L13	Z83L13	Z983L13	Z973L13	43L13	473L13	4773L13	Z493L13	Z4893L13	Z4973L13
3L14	73L14	773L14	Z93L14	Z993L14	Z973L14	43L14	473L14	4773L14	Z493L14	Z4993L14	Z4973L14
3L15	73L15	773L15				43L15	473L15	4773L15			
3L16	73L18	773L16				43L16	473L16	4773L16			
3L17	73L17	773L17				43L17	473L17	4773L17			
3L18	73L18	773L18				43L18	473L18	4773L18			
3L19	73L18	773L19				★43L18	★473L19	★4773L18			
3L20	73L20	773L20				43L20	473L20	4773L20			
3L21	73L21	773L21				43L21	473L21	4773L21			
3LL22	.....	......				.....	.....	......			
3L22	73L22	773L22				43L22	473L22	4773L22			
3L24	73L24	773L24				43L24	473L24	4773L24			
3L26	★73L26	★773L28				43L26	★473L26	★4773L26			
3L28	73L28	773L28				43L28	473L28				
3L30											
3L36											
3L38											

DIMENSIONS





basic bearing number	bore B mm	bore B inch	diameter D mm	diameter D inch	width W mm	width W inch	balls dia.	balls no.	§radius r	†snap ring V	†snap ring T	†snap ring S
3L00	10	.3937	26	1.0236	8	.3150	3/16	7	.012			
3L01	12	.4724	28	1.1024	8	.3150	3/16	8	.012			
3LL02	15	.5906	28	1.1024	7	.2756	5/32	10	.012	...	...	...
3L02	15	.5906	32	1.2598	9	.3543	3/16	9	.012	1 7/16	.042	.120
3LL03	17	.6693	30	1.1811	7	.2756	5/32	11	.012	...	...	...
3L03	17	.6693	35	1.3780	10	.3937	3/16	10	.012	1 25/64	.042	.120
3LL04	20	.7874	37	1.4567	9	.3543	.210	10	.012	...	...	...
3L04	20	.7874	42	1.6535	12	.4724	1/4	9	.025	1 13/16	.042	.120
3LL05	25	.9843	42	1.6535	9	.3543	.210	12	.012	...	...	...
3L05	25	.9843	47	1.8504	12	.4724	1/4	10	.025	2 1/16	.042	.120
3L06	30	1.1811	55	2.1654	13	.5118	9/32	11	.040	2 3/8	.042	.120
3L07	35	1.3780	62	2.4409	14	.5512	5/16	11	.040	2 21/32	.065	.143
3LL08	40	1.5748	62	2.4409	12	.4724	1/4	14	.025	...	...	...
3L08	40	1.5748	68	2.6772	15	.5906	5/16	12	.040	2 59/64	.065	.159
3L09	45	1.7717	75	2.9528	16	.6299	11/32	13	.040	3 13/64	.065	.159
3L10	50	1.9685	80	3.1496	16	.6299	11/32	14	.040	3 13/32	.065	.159
3L11	55	2.1654	90	3.5433	18	.7087	13/32	13	.040	3 51/64	.095	.204
3LL12	60	2.3622	85	3.3465	13	.5118	5/16	17	.040	...	...	...
3L12	60	2.3622	95	3.7402	18	.7087	13/32	14	.040	3 63/64	.095	.204
3L13	65	2.5591	100	3.9370	18	.7087	13/32	15	.040	4 3/16	.095	.204
3L14	70	2.7559	110	4.3307	20	.7874	15/32	14	.040	4 37/64	.095	.204
3L15	75	2.9528	115	4.5276	20	.7874	15/32	15	.040	4 25/32	.095	.204
3L16	80	3.1496	125	4.9213	22	.8661	17/32	14	.040	5 11/64	.109	.218
3L17	85	3.3465	130	5.1181	22	.8661	17/32	15	.040	5 1/2	.109	.218
3L18	90	3.5433	140	5.5118	24	.9449	19/32	14	.060	5 57/64	.109	.250
3L19	95	3.7402	145	5.7087	24	.9449	19/32	15	.060	6 5/64	.109	.250
3L20	100	3.9370	150	5.9055	24	.9449	19/32	15	.060	6 9/32	.109	.250
3L21	105	4.1339	160	6.2992	26	1.0236	21/32	15	.080	6 43/64	.109	.250
3LL22	110	4.3307	150	5.9055	20	.7874	1/2	19	.040	...	...	...
3L22	110	4.3307	170	6.6929	28	1.1024	23/32	14	.080	7 3/16	.120	.261
3L24	120	4.7244	180	7.0866	28	1.1024	23/32	15	.080	7 19/32	.120	.261
3L26	130	5.1181	200	7.8740	33	1.2992	13/16	15	.080	8 3/8	.120	.339
3L28	140	5.5118	210	8.2677	33	1.2992	13/16	16	.080	8 49/64	.120	.339
3L30	150	5.9055	225	8.8583	35	1.3780	7/8	16	.080			
3L36	180	7.0866	280	11.0236	46	1.8110	1 1/8	15	.080			
3L38	190	7.4803	290	11.4173	46	1.8110	1 1/8	16	.080			

BEARING SELECTION

When selecting the correct type and size of bearing, the expected operating conditions of load, speed and desired life must be carefully considered. Knowing these and understanding the information and examples contained in this section, the most satisfactory bearing for the particular application may be readily chosen.

Capacity ratings for New Departure ball bearings are based on detailed mathematical analysis of laboratory testing and field experience covering a span of over fifty years. The criterion of normal bearing life is metal fatigue of contacting surfaces. This fatigue results from repeated high stress on the ball and raceways and is evidenced by material breaking away from the surfaces. The length of bearing service, under operating conditions until fatigue failure, is known as normal *bearing life*. Premature failures from other causes can usually be prevented by proper design, mounting, lubrication and maintenance. When selecting a bearing, the designer should consider any conditions which may adversely affect its life. A few examples of these are: heavy shock load, extremes or wide variation in temperature and or load, vibrating, rotating or oscillating loads, cyclical variations in loads or speeds, and the possibility of bearing contamination from moisture or abrasive material. Where conditions such as the above are anticipated, it is suggested that you contact your New Departure Sales Engineer for expert advice and, if possible, perform simulated service testing.

If a large group of apparently identical bearings is tested to fatigue failure under the same conditions of load and speed, a variation in bearing lives will be noted. The distribution of failures within such a test group follows a probability curve. The form and proportions of the curve are typical of fatigue distribution and remain much the same for all sizes, types, and makes of ball bearings.

The average life of a large group of bearings of a given size is used as the basis for the load rating of that size. The consistency of the average life of groups of apparently identical bearings taken from different production runs, tested under identical conditions, is a measure of product reliability. New Departure's continual testing program indicates a close correlation of results for bearings of different production runs. This is attributed to proper material selection, statistical inspections during manufacture and other quality controls, the use of modern equipment, efficient production methods, and consistently fine craftmanship.

For a given type and size of bearing, life, expressed in hours, depends on the applied load and operating speed of the bearing. The load determines the magnitude of stress and the speed determines the frequency of stress repetitions. For a given load, hours of life varies inversely as bearing speed in rpm. For a given speed, hours of life varies inversely as the fourth power of the applied load.

Life, Capacity, Load Relationship

The relation between the average life, capacity (or load rating), and load in New Departure ball bearings is represented by the following formula:

$$\text{LIFE} = 3800 \left(\frac{\text{CAPACITY}}{\text{LOAD}}\right)^4$$

Where:

Life = Average bearing life, hours.

3800 = Arbitrarily selected factor representing average hours life attained by test lots of production bearings under standard conditions of speed and load.

Capacity (C) = Catalog load rating of bearing at speed concerned.

Load (R_E) = Equivalent radial load on bearing at speed concerned.

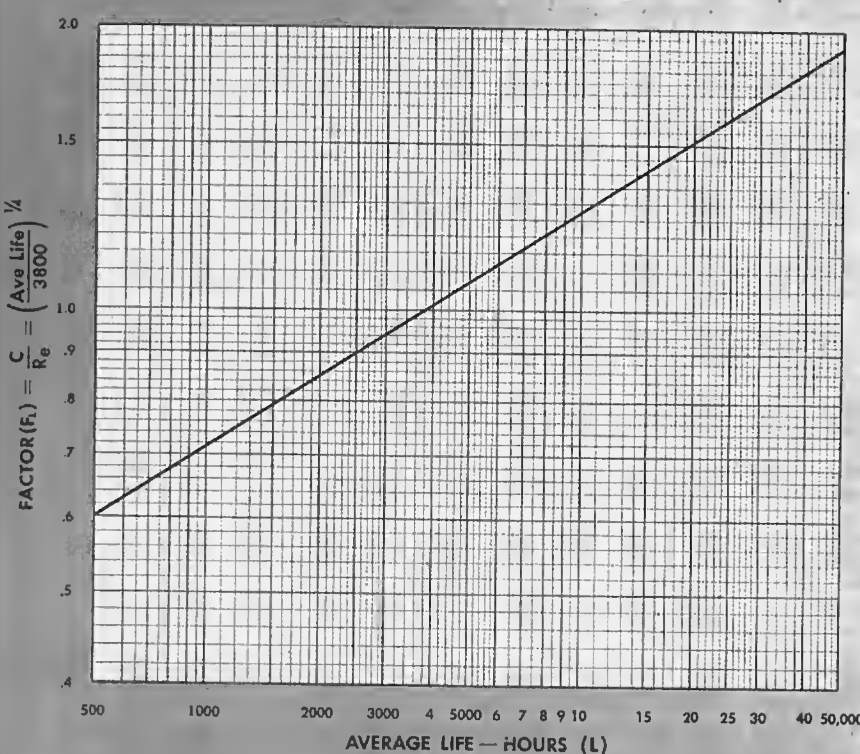
Note:

Capacity/Load is often referred to as the "Load Factor" or "Load-Life Factor", or $C/R_E = F_L$

For convenience in quick calculations the function $F_L = C/R_E = \left(\frac{\text{Life}}{3800}\right)^{1/4}$ is plotted on logarithmic co-ordinates: (See figure 1).

FIGURE 1

LIFE - CAPACITY - LOAD CHART



Accordingly, to determine the average life when the catalog capacity of a chosen bearing and the load to be applied on the bearing are known, a point representing C/R_E (or F_L) is established on the chart ordinate (vertical scale), and the answer is read on the abscissa (horizontal scale).

To determine the required catalog capacity at operating speed when the applied load and desired life are established:

1. Locate the average life on the horizontal scale of the chart and read the C/R_E value off the vertical scale.
2. Multiply this C/R_E value by the applied load.

BEARING SELECTION (cont.)

To determine the maximum constant load which could be applied to a bearing when the bearing capacity at operating speed and desired life are established:

1. Locate average life on the horizontal scale of the chart and read the C/R_E value off the vertical scale.
2. Divide the bearing capacity at operating speed by this C/R_E value.

Bearing life may also be specified in terms of B-10 life rather than average life. B-10 life is defined as the life (in hours at a given speed) which 90% of the bearings in a test group will equal or exceed, under a specific test load. B-10 life is approximately one-fifth of average life. Hence, selecting a bearing on the basis of 3000 hours B-10 life is the same as selecting it on the basis of 15,000 hours average life. Load ratings at several speeds are listed for each bearing in tables following the tables of dimensions. For convenience, the load rating at 1000 rpm is designated as the basic load rating.

To determine the load rating at an operating speed not listed in the tables, the basic load rating must be multiplied by an appropriate Speed Factor corresponding to the operating speed. The speed factor, F_S, can be computed for any design speed (rpm) from the formula:

$$F_S = \left(\frac{1000}{\text{design speed}}\right)^{1/4}$$

Speed Factors for speeds from 10 rpm to 50,000 rpm are given in the chart on page 38.

Thrust Load Ratings

Only radial load ratings are given for Conrad type and maximum capacity type single row bearings. Thrust ratings for Conrad types are equal to radial ratings. Maximum capacity single row bearings (Type 1000) are not recommended for pure thrust loads. For double row and angular contact bearings, the radial and thrust ratings are listed in separate tables.

Thrust load ratings are used only when the ratio of applied thrust to applied radial load is greater than 10. In such cases, the actual thrust load is used as the bearing load, and the thrust rating at operating speed is used as the bearing load rating. Under all other conditions of loading, the radial load rating is used.

Load Ratings for Duplex Sets of Angular Contact Bearings

When two single row angular contact bearings are used as a duplex pair (DB, DF, or DT type mounting — see page 32), the radial load rating of the pair is 1.62 times the radial load rating of a single bearing.

The thrust load rating of a duplex pair mounted DT is 1.62 times the thrust load rating of a single bearing. In DB and DF sets operating under thrust, one bearing carries all the external thrust load. Hence, the thrust load rating of the pair is the same as that of one of the bearings.

Equivalent Radial Load

Bearing load ratings are given as pure radial capacity or pure thrust capacity, but the loads encountered in service are usually combinations of thrust and radial components. To correlate the actual condition of loading with the radial load rating, the Equivalent Radial Load, R_E, is employed. This is a calculated pure radial load which, if applied to the bearing, would result in the same bearing life as that obtained under the actual condition of combined loading.

To convert combined loads to an equivalent radial load, use the appropriate Combined Load Factor, F_C, from the chart on page 39. The chart lists factors, F_C, for various types of bearings for a wide range of ratios of applied thrust, T, to applied radial load, R.

The equivalent radial load, R_E, is computed by multiplying the applied radial load, R, by the factor, F_C.

Where the bearing load is a pure radial load, or where the radial load exceeds 20 times the thrust load, the equivalent radial load can be considered as the applied radial load.

Where the thrust load exceeds 10 times the radial load, the combined load is considered as pure thrust and the thrust rating of the bearing is used.

SPEED FACTORS F_S

rpm	F_S	rpm	F_S	rpm	F_S	rpm	F_S	rpm	F_S	rpm	F_S	rpm	F_S
		360	1.291	1275	.9411	2800	.7731	5100	.6654	9600	.5681	30500	.4255
10	3.162	370	1.282	1300	.9365	2850	.7696	5200	.6622	9700	.5666	31000	.4238
15	2.858	380	1.274	1325	.9321	2900	.7663	5300	.6591	9800	.5652	31500	.4221
20	2.659	390	1.265	1350	.9277	2950	.7630	5400	.6560	9900	.5637	32000	.4204
25	2.515	400	1.257	1375	.9235	3000	.7598	5500	.6530	10000	.5624	32500	.4188
30	2.403	410	1.250	1400	.9193	3050	.7567	5600	.6501	10500	.5555	33000	.4172
35	2.312	420	1.242	1425	.9153	3100	.7536	5700	.6472	11000	.5491	33500	.4157
40	2.236	430	1.235	1450	.9113	3150	.7506	5800	.6444	11500	.5430	34000	.4141
45	2.171	440	1.228	1475	.9074	3200	.7477	5900	.6416	12000	.5373	34500	.4128
50	2.115	450	1.221	1500	.9036	3250	.7448	6000	.6389	12500	.5318	35000	.4111
55	2.065	460	1.214	1525	.8999	3300	.7419	6100	.6363	13000	.5266	35500	.4097
60	2.021	470	1.208	1550	.8962	3350	.7392	6200	.6337	13500	.5217	36000	.4082
65	1.981	480	1.201	1575	.8926	3400	.7364	6300	.6312	14000	.5170	36500	.4068
70	1.944	490	1.195	1600	.8891	3450	.7337	6400	.6287	14500	.5125	37000	.4055
75	1.911	500	1.189	1625	.8857	3500	.7311	6500	.6263	15000	.5081	37500	.4041
80	1.880	525	1.175	1650	.8823	3550	.7285	6600	.6239	15500	.5040	38000	.4028
85	1.852	550	1.161	1675	.8790	3600	.7260	6700	.6215	16000	.5000	38500	.4015
90	1.826	575	1.149	1700	.8758	3650	.7235	6800	.6193	16500	.4962	39000	.4002
95	1.801	600	1.136	1725	.8726	3700	.7210	6900	.6170	17000	.4925	39500	.3989
100	1.778	625	1.125	1750	.8695	3750	.7186	7000	.6148	17500	.4889	40000	.3976
110	1.736	650	1.114	1775	.8664	3800	.7162	7100	.6126	18000	.4855	40500	.3964
120	1.699	675	1.103	1800	.8633	3850	.7139	7200	.6105	18500	.4822	41000	.3952
130	1.665	700	1.093	1825	.8604	3900	.7116	7300	.6084	19000	.4790	41500	.3940
140	1.635	725	1.084	1850	.8575	3950	.7093	7400	.6063	19500	.4759	42000	.3928
150	1.607	750	1.075	1875	.8546	4000	.7071	7500	.6043	20000	.4729	42500	.3917
160	1.581	775	1.066	1900	.8518	4050	.7049	7600	.6023	20500	.4700	43000	.3905
170	1.557	800	1.057	1925	.8490	4100	.7027	7700	.6003	21000	.4671	43500	.3893
180	1.535	825	1.049	1950	.8462	4150	.7006	7800	.5984	21500	.4644	44000	.3883
190	1.515	850	1.041	1975	.8436	4200	.6985	7900	.5965	22000	.4617	44500	.3872
200	1.495	875	1.034	2000	.8409	4250	.6965	8000	.5946	22500	.4591	45000	.3861
210	1.477	900	1.027	2050	.8357	4300	.6944	8100	.5928	23000	.4566	45500	.3850
220	1.460	925	1.020	2100	.8307	4350	.6924	8200	.5910	23500	.4542	46000	.3840
230	1.444	950	1.013	2150	.8258	4400	.6905	8300	.5892	24000	.4518	46500	.3830
240	1.429	975	1.006	2200	.8211	4450	.6885	8400	.5874	24500	.4495	47000	.3819
250	1.414	1000	1.000	2250	.8165	4500	.6866	8500	.5856	25000	.4472	47500	.3809
260	1.400	1025	.9938	2300	.8120	4550	.6847	8600	.5840	25500	.4450	48000	.3799
270	1.387	1050	.9878	2350	.8077	4600	.6828	8700	.5823	26000	.4428	48500	.3789
280	1.375	1075	.9821	2400	.8034	4650	.6810	8800	.5806	26500	.4407	49000	.3780
290	1.363	1100	.9765	2450	.7993	4700	.6792	8900	.5790	27000	.4387	49500	.3770
300	1.351	1125	.9710	2500	.7953	4750	.6774	9000	.5774	27500	.4367	50000	.3761
310	1.340	1150	.9657	2550	.7914	4800	.6756	9100	.5758	28000	.4347		
320	1.330	1175	.9605	2600	.7875	4850	.6738	9200	.5742	28500	.4328		
330	1.320	1200	.9554	2650	.7838	4900	.6721	9300	.5726	29000	.4309		
340	1.310	1225	.9506	2700	.7801	4950	.6704	9400	.5711	29500	.4291		
350	1.300	1250	.9457	2750	.7765	5000	.6687	9500	.5696	30000	.4273		

Note: Use of this chart should be guided by other considerations as outlined in the Limiting Speed Section pages 22 to 24.

BEARING SELECTION (cont.)

LOAD CONVERSION FACTORS

bearing type	combined load factor F_0
Single Row Radial Bearings, Type 1000	column A. For $\frac{T}{R}$ values above .6, consult New Departure Sales Engineer
Single Row Radial Bearings, Types 30, 3LL00, 3L00, 3000, 8000 and Inch Series Type R	column A
Single Row Angular Contact, Types OL00 and 20000	column B
Single Row Angular Contact, Type HOL00 and H20000	column C
Single Row Angular Contact, Type 30000	column D
Duplex bearings, Types OL00 and 20000 mounted DF and DB (radial ratings for a pair of bearings must be used — See page 37)	column E
Duplex bearings, Types HOL00 and H20000 mounted DF and DB (radial ratings for a pair of bearings must be used).	column F
Double row bearings, Types 5000 and 5000W, open or shielded.	column F
Duplex bearings, Type 30000 mounted DF and DB (radial ratings for a pair of bearings must be used). Also 5307WM	column G
Duplex Bearings, Type OL00 DT, HOL00 DT, 20000 DT, H20000 DT, 30000 DT	Consult New Departure Sales Engineer

$\frac{T}{R}$	A	B	C	D	E	F	G
.05	1.01	1.00	1.00	1.00	1.04	1.03	1.01
.10	1.02	1.00	1.00	1.00	1.09	1.07	1.02
.15	1.04	1.00	1.00	1.00	1.14	1.10	1.04
.20	1.06	1.00	1.00	1.00	1.19	1.14	1.06
.25	1.09	1.00	1.00	1.00	1.24	1.17	1.09
.30	1.12	1.00	1.00	1.00	1.30	1.21	1.12
.35	1.16	1.00	1.00	1.00	1.37	1.25	1.16
.40	1.20	1.01	1.00	1.00	1.44	1.29	1.20
.45	1.24	1.01	1.00	1.00	1.51	1.33	1.24
.50	1.28	1.02	1.01	1.00	1.58	1.37	1.28
.60	1.37	1.02	1.02	1.00	1.73	1.46	1.34
.70	1.46	1.07	1.03	1.01	1.88	1.55	1.42
.80	1.56	1.15	1.05	1.01	2.02	1.64	1.50
.90	1.67	1.22	1.08	1.02	2.16	1.74	1.57
1.00	1.77	1.30	1.13	1.02	2.30	1.83	1.63
1.25	2.02	1.50	1.22	1.06	2.68	2.07	1.82
1.50	2.27	1.70	1.31	1.15	3.03	2.31	2.00
1.75	2.52	1.92	1.48	1.23	3.38	2.56	2.20
2.00	2.77	2.14	1.63	1.32	3.77	2.83	2.38
3.00	3.77	3.05	2.27	1.75	5.39	3.91	3.12
4.00	4.76	3.98	2.93	2.22	7.01	5.03	3.88
5.00	5.77	4.92	3.62	2.70	8.64	6.17	4.68
7.50	8.27	7.29	5.33	3.96	12.70	9.02	6.79
10.00	10.77	9.67	7.07	5.23	16.73	11.90	8.92

[illegible]

TYPES 3LL00 3L00

SINGLE ROW RADIAL EXTRA-EXTRA-LIGHT AND EXTRA-LIGHT SERIES

* RADIAL LOAD RATINGS based on average life of 3800 hours

The bearing capacities listed on this page are basic radial load ratings in pounds. From these ratings bearings of the proper size for the service desired can readily be selected by use of data given under "Bearing Selection". For capacities under thrust or combined loads, use factors "F" given under "Bearing Selection".

Thrust ratings are equal to radial ratings, but thrust loads imposed on rotating bearings should not exceed limiting thrust ratings.

basic bearing number	revolutions per minute											†equal running limiting ratings (lbs.)	
	50	100	300	500	720	1000	1200	1800	2500	3600	5000	thrust	radial
3L00	410	345	265	230	210	195	185	170	155	140	130	540	360
3L01	450	380	285	255	235	215	205	185	170	155	140	615	435
3LL02	354	298	227	200	182	168	160	145	134	122	112	560	430
3L02	485	410	310	275	250	230	220	200	185	165	155	700	520
3LL03	380	320	243	214	195	180	172	155	143	131	120	156	480
3L03	520	440	335	295	265	245	235	210	195	180	165	785	595
3LL04	665	560	426	374	342	315	301	272	251	229	211	1060	760
3L04	900	755	575	505	460	425	405	365	340	310	285	1270	925
3LL05	750	630	480	422	385	355	339	307	282	258	237	1280	940
3L05	965	810	615	545	495	455	435	395	360	330	305	1440	1080
3L06	1330	1120	850	750	685	630	600	545	500	455	420	2030	1520
3L07	1660	1400	1060	935	855	785	750	680	625	570	525	2530	1900
3LL08	1200	1010	770	678	618	570	545	492	454	414	381	2100	1600
3L08	1760	1480	1130	990	905	835	800	720	665	605	560	2760	2130
3L09	2270	1910	1450	1270	1160	1070	1020	925	850	775	715	3660	2790
3L10	2380	2000	1520	1340	1230	1130	1080	975	900	820	755	3940	3070
3L11	3240	2730	2070	1820	1660	1530	1460	1320	1220	1110		5140	3930
3LL12	2240	1885	1430	1260	1150	1050	1010	914	844	770	708	4100	2950
3L12	3410	2870	2180	1920	1750	1610	1540	1390	1280	1170		5540	4290
3L13	3570	3000	2280	2010	1840	1690	1610	1460	1340	1230		5940	4680
3L14	4520	3800	2890	2540	2320	2140	2040	1850	1700	1550		7450	5720
3L15	4730	3980	3030	2660	2430	2240	2140	1930	1780	1630		7980	6230
3L16	5590	4700	3570	3150	2870	2640	2520	2280	2100	1920		9630	7420
3L17	5850	4920	3740	3290	3010	2770	2650	2390	2200	2010		10325	8000
3L18	6750	5680	4310	3800	3460	3190	3050	2750	2540			12075	9280
3L19	7070	5940	4520	3970	3630	3340	3190	2880	2660			12925	10000
3L20	7070	5940	4520	3970	3630	3340	3190	2880	2660			12925	10050
3L21	8280	6960	5290	4660	4250	3910	3740	3380	3120			15850	12225
3LL22	6120	5150	3920	3450	3150	2900	2770	2500	2310	2110	1940	12200	8400
3L22	9220	7750	5890	5180	4730	4360	4170	3760	3470			17775	13625
3L24	9650	8120	6170	5430	4950	4560	4360	3940	3630			19050	14750
3L26	11475	9650	7340	6460	5900	5430	5190	4690	4320			24475	18825
3L28	11975	10075	7660	6740	6160	5670	5420	4890				26125	20225
3L30	13375	11250	8550	7520	6860	6320	6040	5460				30350	23425
3L36	18325	15400	11700	10300	9400	8660	8270					47275	36125
3L38	19125	16075	12225	10750	9820	9040	8640					51275	38900

ABEC 1 TOLERANCES

SHAFT MOUNTING FITS

SINGLE ROW RADIAL
SINGLE ROW ANGULAR CONTACT
DOUBLE ROW
N/D SEAL BEARINGS

For Type 30, Type R, irregularly numbered N/D Seal Bearings, and derivatives, see pages 170 and 173.

The fits given in this table are satisfactory for nearly all general or average bearing applications. However, for some mounting conditions, certain modifications of these fits may be required.

In general, soft shafts, those not having smoothly ground bearing seats, and those subject to very heavy or vibratory loads, need tighter than average fits. Correct fits for any special conditions will be supplied by your New Departure Sales Engineer.

For explanation of "Expected Fits" listed below, see pages 157-159. Note discussion regarding allowance for bearing taper and unroundness on pages 155 and 156.

bearing bore numbers	bearing bore		shaft revolving						shaft stationary					
	diameters		diameters		expected fit		theoret. fit		diameters		expected fit		theoret. fit	
	max.	min.	max.	min.	loose or tight	tight	loose	tight	max.	min.	max. loose	min. loose	loose	tight
0 1 2	.3937 .4724 .5906	.3934 .4721 .5903	.3939 .4726 .5908	.3936 .4723 .5905	.0000L	.0004	.0001	.0005	.3935 .4722 .5904	.3932 .4719 .5901	.0004	.0000	.0005	.0001
3 4 5	.6693 .7874 .9843	.6690 .7870 .9839	.6695 .7877 .9846	.6692 .7873 .9842	.0000L .0000L .0000L	.0004 .0006 .0006	.0001 .0001 .0001	.0005 .0007 .0007	.6691 .7871 .9840	.6688 .7867 .9836	.0004 .0006 .0006	.0000 .0000 .0000	.0005 .0007 .0007	.0001 .0001 .0001
6 7 8	1.1811 1.3780 1.5748	1.1807 1.3775 1.5743	1.1814 1.3784 1.5752	1.1810 1.3779 1.5747	.0000L .0001T .0001T	.0006 .0007 .0007	.0001 .0001 .0001	.0007 .0009 .0009	1.1808 1.3776 1.5744	1.1804 1.3771 1.5739	.0006 .0007 .0007	.0000 .0001 .0001	.0007 .0009 .0009	.0001 .0001 .0001
9 10 11	1.7717 1.9685 2.1654	1.7712 1.9680 2.1648	1.7721 1.9689 2.1659	1.7716 1.9684 2.1653	.0001T .0001T .0001T	.0007 .0007 .0009	.0001 .0001 .0001	.0009 .0009 .0011	1.7713 1.9681 2.1649	1.7708 1.9676 2.1643	.0007 .0007 .0009	.0001 .0001 .0001	.0009 .0009 .0011	.0001 .0001 .0001
12 13 14	2.3622 2.5591 2.7559	2.3616 2.5585 2.7553	2.3627 2.5596 2.7564	2.3621 2.5590 2.7558	.0001T	.0009	.0001	.0011	2.3617 2.5586 2.7554	2.3611 2.5580 2.7548	.0009	.0001	.0011	.0001
15 16 17	2.9528 3.1496 3.3465	2.9522 3.1490 3.3457	2.9533 3.1501 3.3471	2.9527 3.1495 3.3464	.0001T .0001T .0002T	.0009 .0009 .0012	.0001 .0001 .0001	.0011 .0011 .0014	2.9523 3.1491 3.3458	2.9517 3.1485 3.3451	.0009 .0009 .0012	.0001 .0001 .0002	.0011 .0011 .0014	.0001 .0001 .0001
18 19 20	3.5433 3.7402 3.9370	3.5425 3.7394 3.9362	3.5439 3.7408 3.9376	3.5432 3.7401 3.9369	.0002T	.0012	.0001	.0014	3.5426 3.7395 3.9363	3.5419 3.7388 3.9356	.0012	.0002	.0014	.0001
21 22 24	4.1339 4.3307 4.7244	4.1331 4.3299 4.7236	4.1345 4.3313 4.7250	4.1338 4.3306 4.7243	.0002T	.0012	.0001	.0014	4.1332 4.3300 4.7237	4.1325 4.3293 4.7230	.0012	.0002	.0014	.0001
26 28 30	5.1181 5.5118 5.9055	5.1171 5.5108 5.9045	5.1188 5.5125 5.9062	5.1179 5.5116 5.9053	.0002T	.0014	.0002	.0017	5.1173 5.5110 5.9047	5.1164 5.5101 5.9038	.0014	.0002	.0017	.0002
32 34 36	6.2992 6.6929 7.0866	6.2982 6.6919 7.0856	6.2999 6.6936 7.0873	6.2990 6.6927 7.0864	.0002T	.0014	.0002	.0017	6.2984 6.6921 7.0858	6.2975 6.6912 7.0849	.0014	.0002	.0017	.0002

ABEC 1 TOLERANCES

HOUSING MOUNTING FITS

SINGLE ROW RADIAL
SINGLE ROW ANGULAR CONTACT
DOUBLE ROW
N/D SEAL BEARINGS

For Type 30, Type R, irregularly numbarad N/D Seal Bearings, and derivatives, see pages 170 and 173.

The fits given in this table are satisfactory for nearly all general or average bearing applications. However, for some mounting conditions, certain modifications of these fits may be required.

In general, soft metal housings, particularly when revolving, and those subject to heavy or vibratory loads, need tighter than average fits. For best results, housings should hava a smooth finish such as produced by grinding or reaming.

In practice the actual fits obtained will be closer than thosa listed under "Theoretical Fits" below. See pages 157-159. Note discussion regarding allowance for bearing taper and unroundness on pages 155 and 156.

bearing bore numbers			bearing outer diam.		housing stationary				housing revolving			
series			diameters		diameters		theoret. fit		diameters		theoret. fit	
ex-lt.	light	med.	max.	min.	max.	min.	tight	loose	max.	min.	tight	loose
0 1	0		1.0236 1.1024 1.1811	1.0232 1.1020 1.1807	1.0240 1.1028 1.1815	1.0235 1.1023 1.1810	.0001	.0008	1.0236 1.1024 1.1811	1.0231 1.1019 1.1806	.0005	.0004
2 3	1 2	0 1	1.2598 1.3780 1.4567	1.2593 1.3775 1.4562	1.2603 1.3785 1.4572	1.2597 1.3779 1.4566	.0001	.0010	1.2598 1.3780 1.4567	1.2592 1.3774 1.4561	.0006	.0005
4 5	3 4	2 3	1.5748 1.8535 1.8504	1.5743 1.6530 1.8499	1.5753 1.6540 1.8509	1.5747 1.6534 1.8503	.0001	.0010	1.5748 1.6535 1.8504	1.5742 1.6529 1.8498	.0008	.0005
6 7	5 6	4 5	2.0472 2.1654 2.4409	2.0467 2.1649 2.4404	2.0477 2.1659 2.4414	2.0471 2.1653 2.4408	.0001	.0010	2.0472 2.1654 2.4409	2.0466 2.1648 2.4403	.0006	.0005
8 9	7	6	2.6772 2.8346 2.9528	2.6767 2.8341 2.9523	2.6777 2.8351 2.9533	2.6771 2.8345 2.9527	.0001	.0010	2.6772 2.8346 2.9528	2.6766 2.8340 2.9522	.0006	.0005
10 11	8 9 10	7 8	3.1496 3.3465 3.5433	3.1491 3.3459 3.5427	3.1501 3.3472 3.5440	3.1495 3.3464 3.5432	.0001 .0001 .0001	.0010 .0013 .0013	3.1496 3.3466 3.5434	3.1490 3.3458 3.5426	.0006 .0007 .0007	.0005 .0007 .0007
12 13 14	11 12	9 10	3.7402 3.9370 4.3307	3.7396 3.9364 4.3301	3.7409 3.9377 4.3314	3.7401 3.9369 4.3306	.0001	.0013	3.7403 3.9371 4.3308	3.7395 3.9363 4.3300	.0007	.0007
15 16	13 14	11	4.5276 4.7244 4.9213	4.5270 4.7238 4.9205	4.5283 4.7251 4.9221	4.5275 4.7243 4.9211	.0001 .0001 .0002	.0013 .0013 .0016	4.5277 4.7245 4.9214	4.5269 4.7237 4.9204	.0007 .0007 .0009	.0007 .0007 .0009
17 18 19	15 16	12 13	5.1181 5.5118 5.7087	5.1173 5.5110 5.7079	5.1189 5.5126 5.7095	5.1179 5.5116 5.7085	.0002	.0016	5.1182 5.5119 5.7088	5.1172 5.5109 5.7078	.0009	.0009
20 21 22	17 18 19	14 15 16	5.9055 6.2992 6.6929	5.9047 6.2982 6.6919	5.9063 6.3002 6.6939	5.9053 6.2990 6.6927	.0002 .0002 .0002	.0018 .0020 .0020	5.9056 6.2993 6.6930	5.9046 6.2981 6.6918	.0009 .0011 .0011	.0009 .0011 .0011
24 26	20 21 22	17 18 19	7.0866 7.4803 7.8740	7.0856 7.4791 7.8728	7.0876 7.4815 7.8752	7.0864 7.4801 7.8738	.0002 .0002 .0002	.0020 .0024 .0024	7.0867 7.4805 7.8742	7.0855 7.4791 7.8728	.0011 .0012 .0012	.0011 .0014 .0014
28 30	24	20 21	8.2677 8.4646 8.8583	8.2665 8.4634 8.8571	8.2689 8.4658 8.8595	8.2675 8.4644 8.8581	.0002	.0024	8.2679 8.4648 8.8585	8.2665 8.4634 8.8571	.0012	.0014
32	26 28	22	9.0551 9.4488 9.8425	9.0539 9.4476 9.8413	9.0563 9.4500 9.8437	9.0549 9.4486 9.8423	.0002	.0024	9.0553 9.4490 9.8427	9.0539 9.4476 9.8413	.0012	.0014
34 36	30	24 26	10.2362 10.6299 11.0236	10.2348 10.6285 11.0222	10.2375 10.6312 11.0249	10.2359 10.6296 11.0233	.0003	.0027	10.2364 10.6301 11.0238	10.2348 10.6285 11.0222	.0014	.0016

ECL-17
M 114a-3

Exhibit 7. Bearing Analysis.

NO. E-9559
SAMPLE 1#73L22X1A

COPIES TO:
INSPECTION A3 D__ W__
MANUFACTURE A__ D__ W__
SALES EASTERN ____
CENTRAL ____ WESTERN E3
MIDWEST ____
ENGINEERING ____
DIR. OF INSPECTION 1

RECEIVED NOV 29 1963 NEW DEPARTURE REDWOOD CITY

NEW DEPARTURE
DIVISION GENERAL MOTORS CORPORATION
SERVICE REPORT

RECEIVED 11/4/63
QUANTITY 1 TAG #
REQUEST REC'D 11/4/63
INSP. ADVISED ____
MFG. ADVISED ____

Food Machinery Corp., Canning Machinery Div. San Jose
CUSTOMER'S NAME AND ADDRESS

REQUESTED BY W.C.W.

LETTER ____
COMP. REP ____

W. C. Willey
REPRESENTATIVE

REFERENCE R.S. 58423

OTHER F/R 37763

~~Los Angeles~~ San Francisco
ZONE

SUBJECT OF INVESTIGATION

This bearing is from a Roto Scan machine which has been in service a few months in customer's plant. It is the same application as bearing reported under SR E-9481 where operation was in lab only. Customer's drawing No. 7380-691593 attached to F/R.

#2 Uncle Ben's #4 Mach (CMD #5)

CONCLUSION

Bearing has not failed but exhibits several detrimental operating conditions viz:

1. Radial preloading
2. Light 3 point housing out-of-roundness
3. Marginal lubrication

ANALYSIS: Bearing was slightly harsh sounding even after thorough cleaning. End-play measured .010. The race load tracks are centrally located and run entirely around the outer race. Since no ring turning is visible this condition indicates radial preloading. Normally we would expect the tracks to be off center to some degree in view of the 150 lb weight of the spindle. Note: ring is clamped!
3600 rpm force may be much greater.

In addition, track in outer race widens noticeably at three points approximately 120° apart. Check of ring O.D. and ball race failed to show any 3 point condition hence it appears likely that the housing was responsible.

The load tracks when examined under low magnification, have the distressed appearance usually associated with marginal lubrication. This could be from breakdown of the lubricating films between balls and races due either to (1) an insufficient amount of the oil actually reaching the load carrying surfaces, (2) too heavy a load for the film to resist, or (3) inadequacy of the lubricant itself under the conditions present.
may be due to product in brg.

Balls are load banded and oxide discolored

RECOMMENDATION

Suggest lubrication system be reviewed. Check particularly whether the oil air mist is being deflected to any extent by the locknut shown in dwg. 7380. Also, if the shield on the opposite side is effectively blocking free circulation of the mist around the balls. Would it be possible to bring the mist in above the bearing? product over shield crack may block mist flow.

con't

DATE OF REPLY 11/19/63
INVESTIGATED BY PFR
APPROVED BY PFR/mi

Engineering Products Lab.
New Departure Division, Bristol, Conn

(2)

Exhibit 7. Bearing Analysis

COPIES TO:

INSPECTION A 3 D W

MANUFACTURE A D W

SALES EASTERN

CENTRAL WESTERN 3

MIDWEST

ENGINEERING 2

DIR. OF INSPECTION 1

LETTER

COMP. REP

OTHER F.R 37718

NEW DEPARTURE

DIVISION GENERAL MOTORS CORPORATION

SERVICE REPORT

RECEIVED OCT 23 1963 NEW DEPARTURE REDWOOD CITY

NO. E-9481

SAMPLE 1#73L22

RECEIVED 10/9/63

QUANTITY 1 TAG #

REQUEST REC'D 10/9/63

INSP. ADVISED

MFG. ADVISED

Food Machinery Corp., Canning Div. San Jose, Cal.

CUSTOMER'S NAME AND ADDRESS

REQUESTED BY K.W.C.

K. W. Conrad

REPRESENTATIVE

REFERENCE R.S. 56089

San Francisco

ZONE

Sastiyo Rotascan Gen. P

SUBJECT OF INVESTIGATION

Bearing is used in "Roto Scan" machine which inspects via optics for defective grain or dehydrated vegetables. It is the upper scan spindle bearing. Speed 3600 rpm in vertical position, spindle weighs 150 lbs. Lower bearing is SKF roller. Oil mist lubrication using shell Tellus #27. Complaint is that 73L22 becomes noisy and has to be replaced.

#1 From ass'y floor!

CONCLUSION

In our opinion the #73L22 is being radially preloaded to the extent that lubrication becomes marginal.

ANALYSIS

Bearing was noisy and rough on sound test here. Endplay measured .0085 (X) specification.

Disassembly showed components to be unfailed. However, the load tracks appear unusually wide and discolored from localized heat (marginal lubrication possible). The tracks are centrally located (no thrust) and in the outer race the width is very nearly uniform, with no evidence of this ring turning in the housing, radial preloading, is indicated.

Balls have heavy discolored load bands, again indicative of preload. No significant mislaignment could be detected.

RECOMMENDATION

Suggest housing and shaft fits be checked. It may be necessary to go to a looser fit up to insure that bearing will not be dangerously preloaded.

DATE OF REPLY 10/18/63

INVESTIGATED BY PFR

APPROVED BY PFR/mi

Courtesy of New Departure.

Exhibit 7. Bearing Analysis

Food Machinery Corporation
San Jose, California

Service Report E-9559

ok

A review of their drawings shows radial pre-loading unlikely if shaft and housing figures are maintained. Suggest units in which this bearing and that of SR E-9431 operated be checked for conformity to print dimensions. In this connection, also check for 3 point condition as it relates to latest bearing returned. ?

checked at assembly - ok

Exhibit 8. Spindle Sub-assembly Parts Costs:

Note: The production cost for the parts listed below include Labor, Burden (Overhead), and Material charges as in the example:

Spindle Adapter - No. 688065

Labor........	$ 11.70
Burden........	20.25
Material	6.99
Total	$ 38.94

Part Description	Part No.	Production Cost
Spindle Adapter	688065	$ 38.94
Spindle	688062	315.00
Dust Cover	688068	55.47

Courtesy of FMC Corporation

Exhibit 8. Spindle Sub-assembly Parts Costs:

Note: The production cost for the parts listed below include Labor, Burden (Overhead), and Material charges as in the example:

Spindle Adapter - No. 688065

Labor........	$ 11.70
Burden.......	20.25
Material	6.99
Total	$ 38.94

Part Description	Part No.	Production Cost
Spindle Adapter	688065	$ 38.94
Spindle	688062	315.00
Dust Cover	688068	55.47

Courtesy of FMC Corporation

ECL-17
ME 114a-3

FMC CORPORATION (D)

Rice Sorter Redesign

Prepared in the Design Division of the Mechanical Engineering Department by J. Kendall Williams under the direction of Karl H. Vesper. The assistance of Dr. T. E. Roberts and Art Slemmons of the Central Engineering Laboratories, and John Boyce, S. H. Creed, and Don Chamberlin of the Canning Machinery Division is gratefully acknowledged. Financial support for this study was provided by the National Science Foundation.

Don Chamberlin's first step to eliminate the bearing failures was to check dimensions and tolerances of the spindle and spindle housing upper bearing fit. He found as he expected that the fit was exactly one recommended in the New Departure Catalogue for the 73L00 Series lightweight bearings. In the process of thoroughly reviewing tolerances, Don specified that the bearing lands should be parallel within 0.005 T.I.R. in 12 inches. This change is described in greater detail in Exhibit 2, page 2.

Don made several design changes to sorter parts working directly on the main assembly drawing. He had spent several days thinking about the changes and made rough sketches at home. He said, "Anyone who wants to quit at 5:00 should forget about engineering. Sometimes I'll wake up in the middle of the night with a solution to a problem." The first change concerned the lubrication system. The New Departure bearing analysis had mentioned faulty lubrication as one possible cause of the bearing failures. Don commented that the mist fitting adjacent to the bearings was not one recommended in the Alemite Oil Mister catalogue. Don decided to use short Alemite fittings and direct the oil mist at the space between the inner and outer race of the ball bearings.

Don's next step was to change the spindle and spindle-adapter to a single piece design in order to insure better alignment of the upper bearing. The new spindle was made of two rough machined parts which were welded together and finish machined in the CMD machine shop. Don commented, "The original drawing didn't even include a note on the finish of the surface mated to the adapter. A decision on the finish should not be left up to the machinist." The new spindle design is described in greater detail in Exhibit 2, page 1.

Don made four design changes to help eliminate rice dust from the upper bearing. First, the original dust deflector assembly was changed from two pieces to one piece. Second, a small lip was provided on the one piece spindle above the new dust deflector. Next, a second dust deflector that completely shielded an area between the flange on the spindle and the spindle housing was added. The new design resulted in an extensive labyrinth dust seal. These changes are indicated in Exhibit 1. Details of the new parts are included in Exhibit 2, pages 3 and 4.

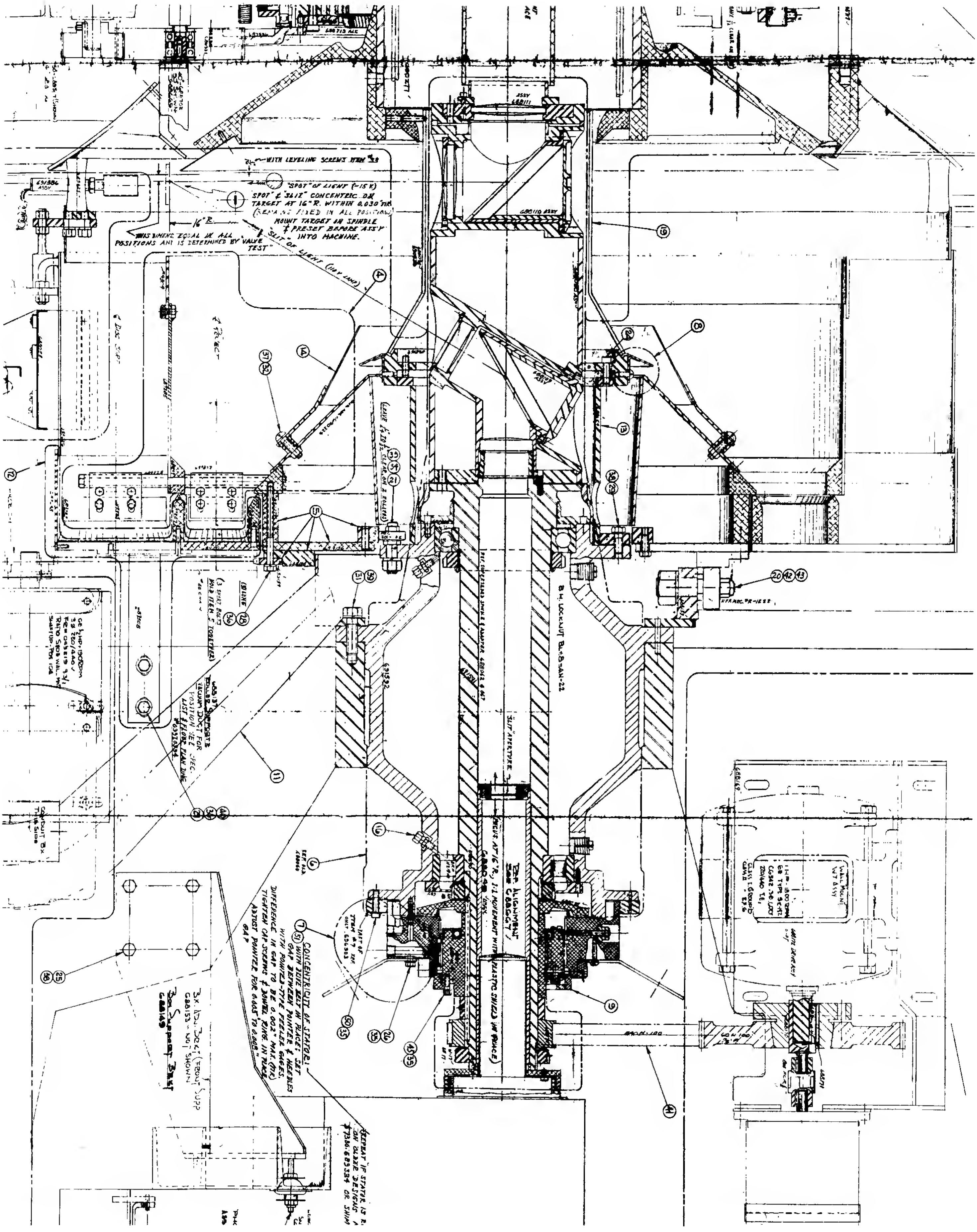
Don estimated that the new parts designs for the bearing area resulted in a $22.28 increase over the previous design. Production costs for the redesigned parts are given in Exhibit 3. "Considering the maintenance, down-time, and saleability, however," Don said, "I think that this expense is more than justified. We have one machine installed at Modesto, California, with these changes, and after three months of operation, there have been no failures in the bearings."

Don also redesigned the housing and commutator mounting parts in order to simplify assembly and timing procedures. He added an extension

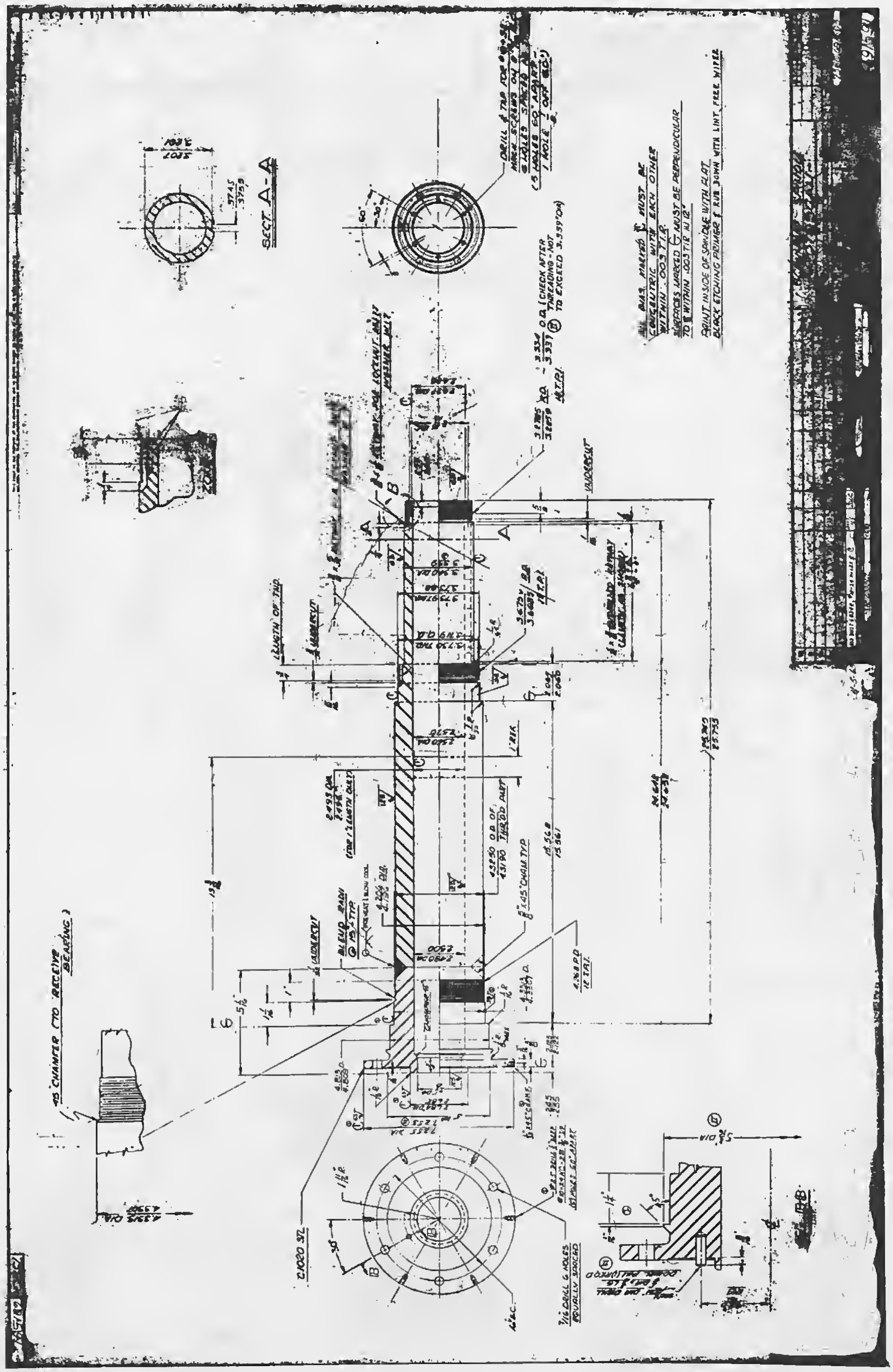
to the housing to take the place of the original commutator spacer. The commutator stator body was still secured to the housing by long machine screws which passed through the elongated holes in the stator body. He designed a new concentricity ring for the commutator. Each new ring was machined and matched to a commutator body, and the two parts were kept together through final assembly of the sorter. The ring was machined to a close running fit to the stator body. During the assembly, the drive belt was installed and the stator and ring assembly was positioned relative to the rotor with a feeler gage and then bolted to the housing lip. Next, the ring and housing drilled and dowel pinned. Don then explained that when the commutator cap screws were loosened to time the machine, the stator needles would remain concentric to the rotor pointer within the concentricity tolerance between the stator body outer diameter and the stator needles. Don put the assembly procedure on the general assembly drawing which was used by the assembly crew to insure proper installation of all parts. The design changes and assembly notes appear in Exhibit 1.

In approaching the redesign, Don made a proposal of work to be accomplished on the sorter design, which he submitted to his supervisor, the Assistant Chief Engineer, prior to initiating any changes. Don said, "I think that it is the engineer's responsibility to think things out as completely as possible before asking for his management's time." In addition to this proposal, Don was responsible for estimating the total and monthly project costs for his work. Typical proposals and cost estimates are included in Exhibit 3, pages 1 and 2.

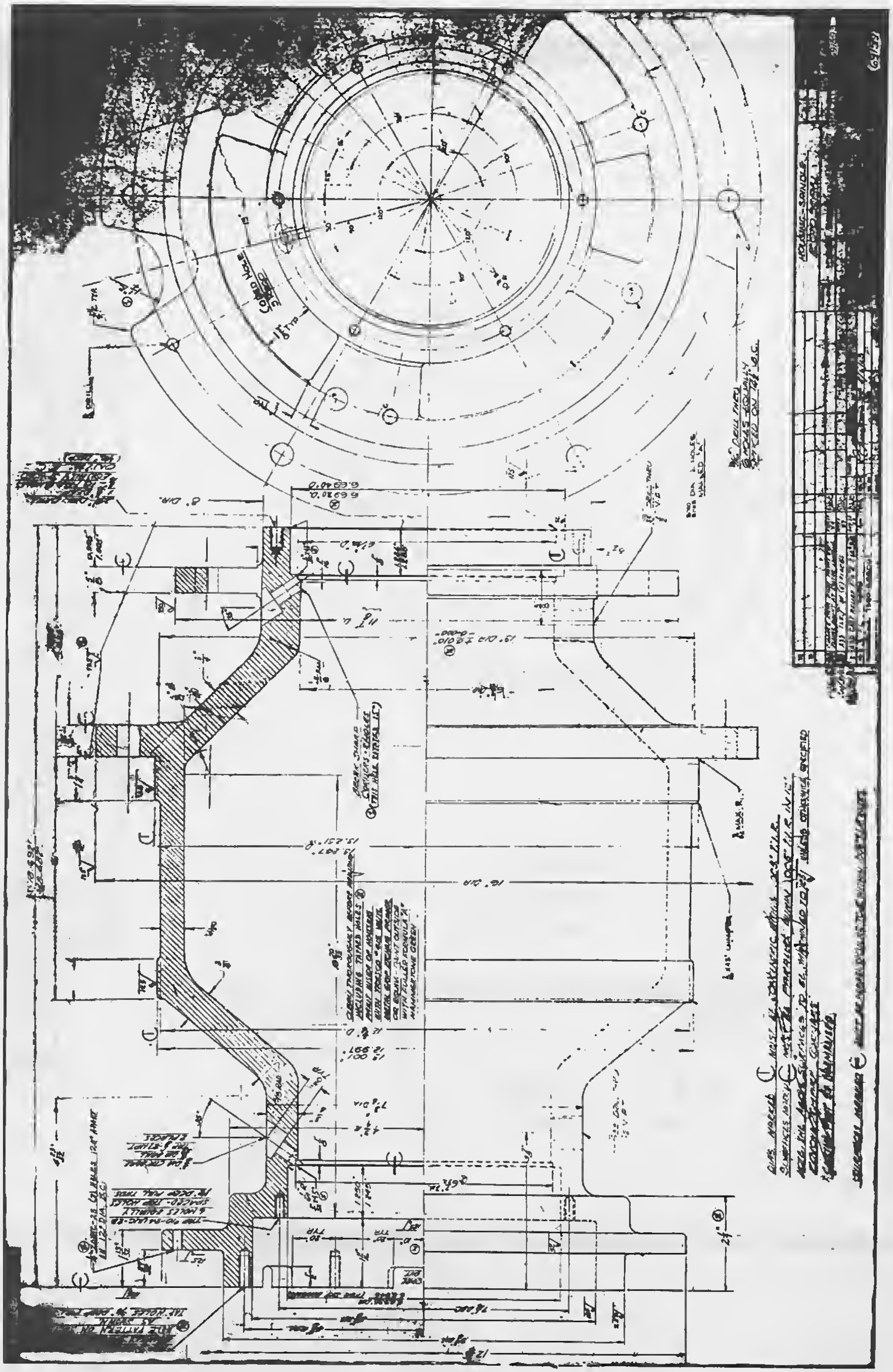
Don said that a continuous record of all design changes was kept on file in Canning Machinery's Reproduction Office. Whenever Don made a change on a drawing, he notified a "parts lister" of the modification by use of an Engineering Change Notice Sheet on which he recorded the changes directly from a drawing and noted the reason and nature of the change. A new or modified parts list was made up from the change sheets. Assembly and subassembly parts lists were kept on each sorter. Whenever a request for a replacement part was received at the sales office from a customer, a production engineer could refer to the parts lists for the customer's machine and locate the drawing for each part ordered. Typical examples of drawing modifications and a corresponding materials list are described in greater detail in Exhibit 4.

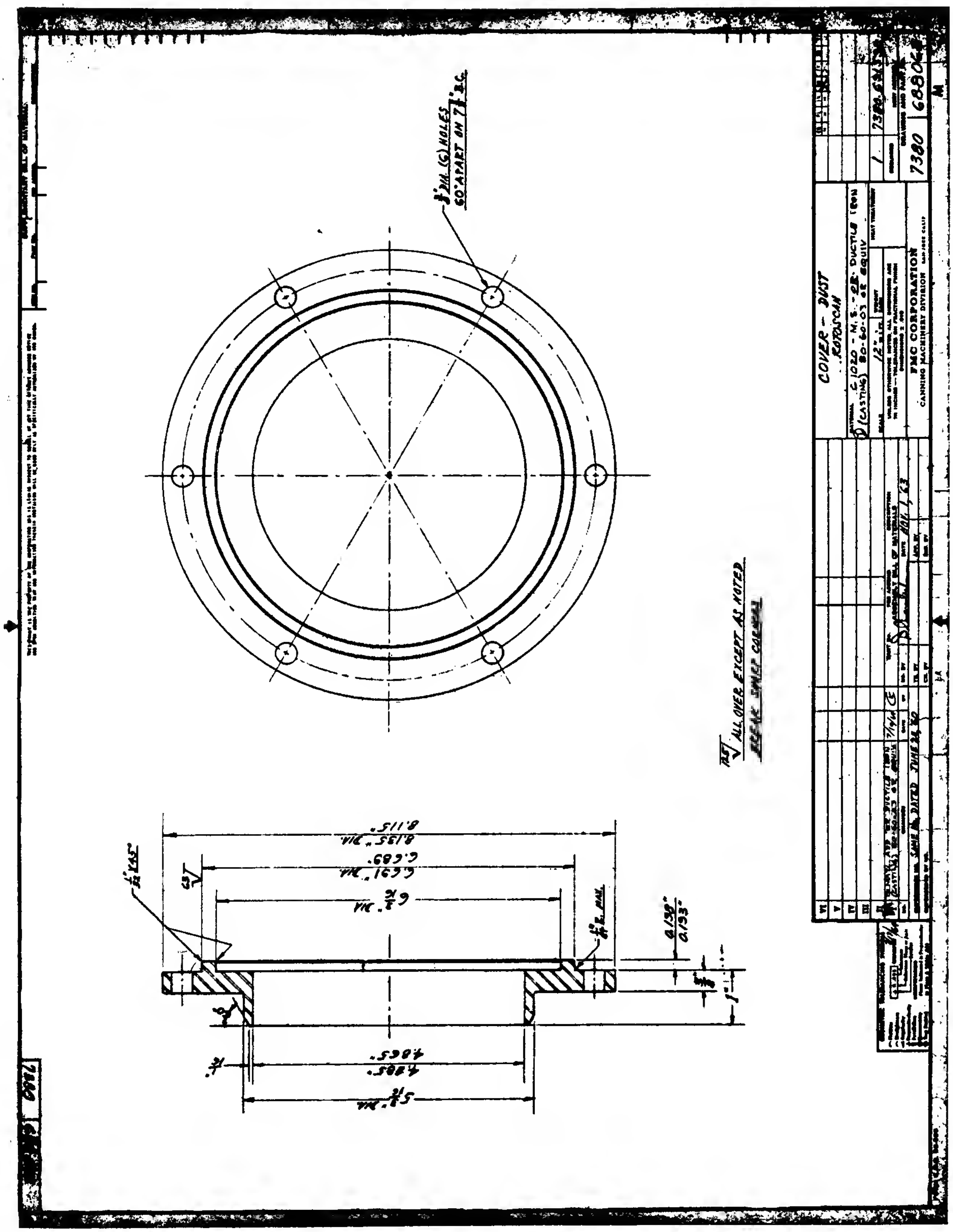


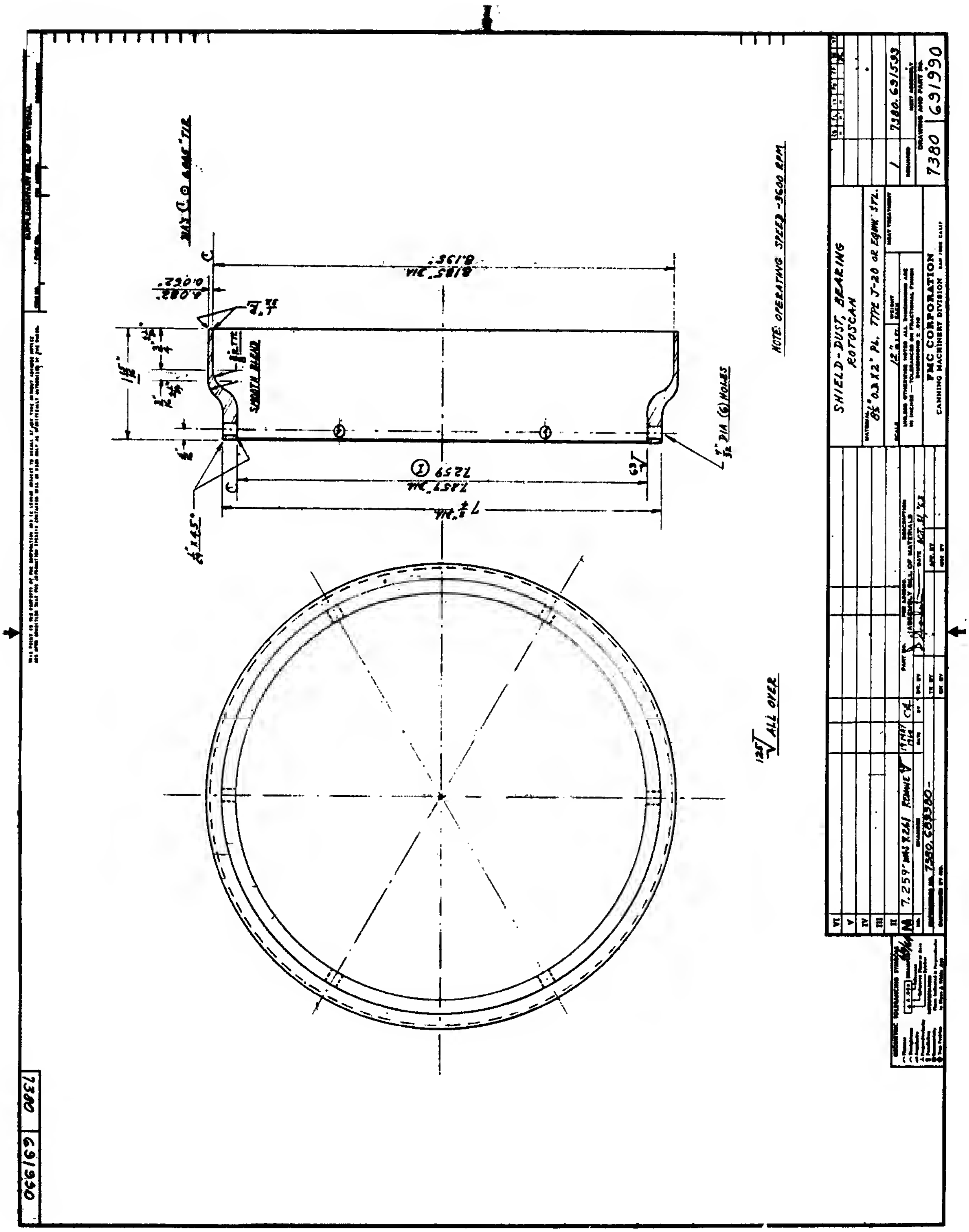
Courtesy of FMC Corporation



Courtesy of FMC Corporation




COVER - DUST
ROTOSCAN
FMC CORPORATION
CANNING MACHINERY DIVISION
7380
6880
ALL OVER EXCEPT AS NOTED
BREAK SHARP CORNERS
8.115"
8.135" DIA.
6.689"
6.691" DIA.
4.865"
4.885"
5 1/2" DIA.
0.190"
0.193"


SHIELD-DUST, BEARING
ROTOSCAN
FMC CORPORATION
CANNING MACHINERY DIVISION
7380
691990
NOTE: OPERATING SPEED -3600 RPM
ALL OVER

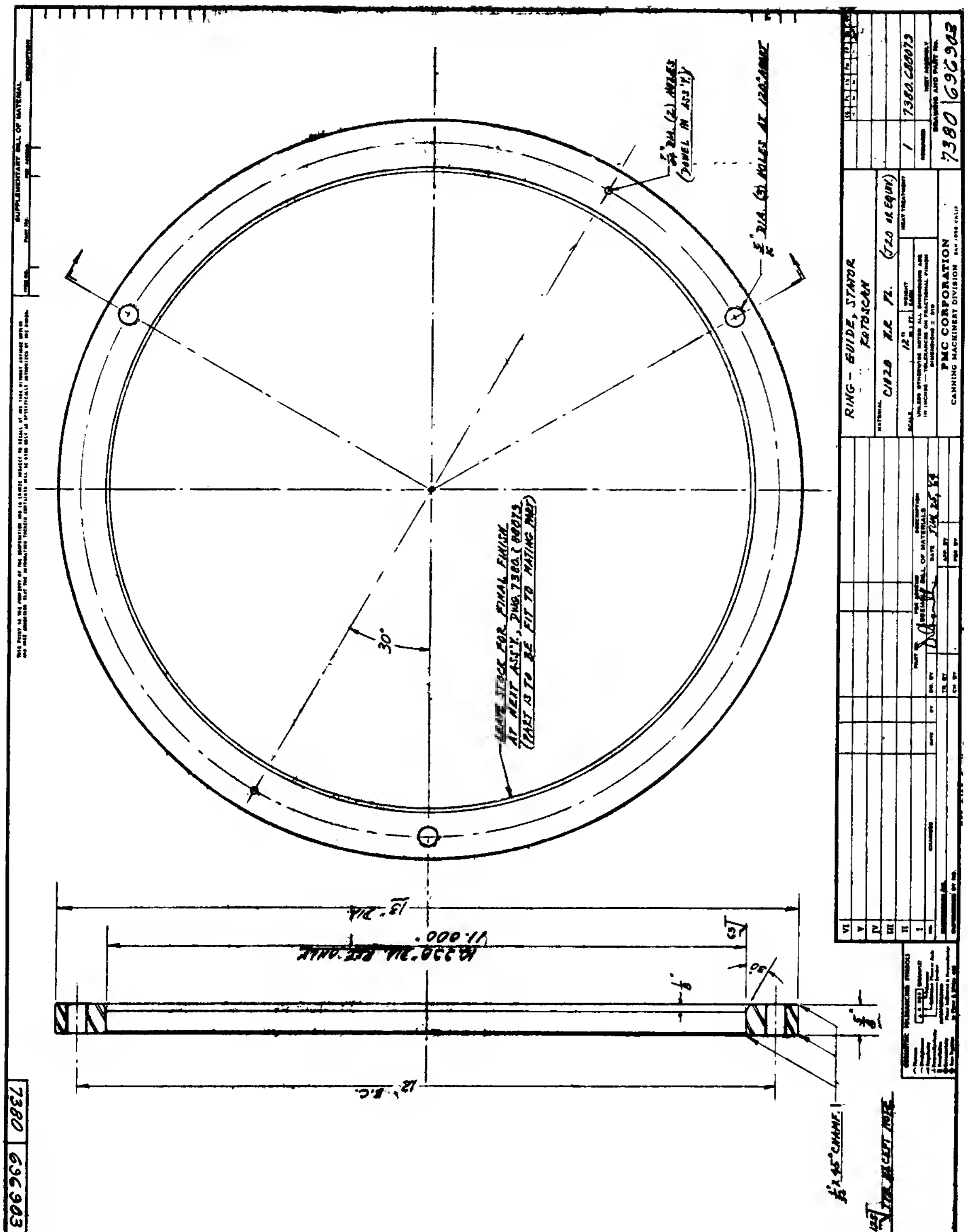


Exhibit 3. Production Costs for Redesigned Spindle Sub-Assembly Parts.

Note: The production costs for the following parts include charges for Labor, Burden, and Material.

Part Description	Part No.	Production Cost
Spindle	691591	$ 384.00
Dust Cover	688068	28.29
Dust Shield	691990	68.00

DETAILED PROJECT PLAN - 1964

62S91

ROTOSCAN IMPROVEMENTS AND EXPLOITATIONS

1)	New product machine modification and testing including bean products. Rework of Riverbrand feed cone.	$2,500.00
2)	Necessary field work to solve possible feed problems with dehydrated apple machine and minor field machine improvements.	1,000.00
3)	Design of commutator dust housing, mirror carriers and other machine improvement.	1,000.00
4)	Electronic modification for functional improvement including an electronic plate current breaker system.	2,500.00
5)	New drawings of above, corrections and improvement changes.	500.00
		$7,500.00

Exhibit 3. Con't. DEVELOPMENT PROJECT PLANNING SHEET BY D. Chamberlin
FOR MONTH OF June 1964 DATE

PROJECT No. 628 91 PROJECT NAME Potasean Improv & Eff

PLANS	ACCOMPLISHMENTS
AT THE FIRST OF THE MONTH, LIST BELOW THE WORK PLANNED FOR THIS PROJECT FOR THE MONTH. ESTIMATE THE COST FOR THIS WORK AND ENTER AT THE BOTTOM OF THE PAGE	AT THE END OF THE MONTH, INDICATE BELOW HOW MUCH OF THE PLANNED PROGRAM WAS ACCOMPLISHED. EXPLAIN MAJOR DEVIATIONS.
— Finish up remaining approx 10% of drawing changes & corrections. — New console dwgs. are needed — Layout of smaller feed gear & guarding should be started $500	Console dwgs almost complete except listing of material etc. Other dwg. changes complete except for minor function & cost changes that come up $827 +49
— Start investigation of future machine improvements including dust housing, & electronic modifications if appropriation request comes thru. $250	We can now start CEL thinking about electronic current breaker assembly ideas.
— Do continuing studies on new feed development as time allows. $500 — Take care of, or explore means for field improvements based on last trip to Consolidated. $500	This will be delayed until drawings are completed for current production of 3 machines $868 We are continuing to look at Consolidated's plastic shield problem & possible elimination of shield

AT THE END OF THE MONTH, LIST THE WORK WHICH WAS DONE DURING THE MONTH WHICH WAS NOT INCLUDED IN THE ABOVE PLAN MADE AT THE BEGINNING OF THE MONTH. GIVE THE REASON FOR THE CHANGE IN PLAN & STATE THE AFFECT ON THE PROJECT BUDGET.

Hydroflex speed recorder — (not on this project)
" jog switch change — " " " "
start Vacu-Dry installation — (on sales order)

ESTIMATED TOTAL EXPENDITURE FOR THE MONTH $1750 ACTUAL EXPENDITURE FOR THE MONTH $1744

Exhibit 4.

ECL-17
M.E. 114a-2

FMC CORPORATION
CANNING MACHINERY DIVISION

ENGINEERING CHANGE NOTICE.

DATE: MAY 18 1964

Copies To:
- [x] ENGINEERING (ORIGINAL)
- [x] PLANNING (OZALID COPY)
- [ ] PATTERN SHOP (OZALID COPY)
- [ ] COST DEPT. (OZALID COPY)
- [ ] OTHER

SHT 1 OF 3

DRAWING NUMBER	PIECE NAME:	PART NUMBER
7380.688089	SCANNING HEAD	7380.688089
SUPERSEDED BY	MACHINE NAME: ROTO SCAN	SUPERSEDED BY

CHG. NO.	DESCRIPTION OF CHANGE
V	WAS: 2" LG. IS: 1 3/4" LG.
	WAS: 1 5/8" (DIM.) IS: 2"
	WAS: 7 1/16" (DIM) IS: 6 11/16"
	WAS: 1 7/8" (DIM) IS: 1 3/4"
	WAS: 4 1/4" (DIM.) IS: 4 3/8"
	REF DIMS, ADDED: 5.012"; 2.463"; 2.093"; .0457"; 1/8"; .072"; 7.105; 7.145
	BAL. NOTE WAS: DYN. BAL. WITHIN .250 OUNCE INCHES EACH PLANE---.
	IS: DYN. BAL. WITHIN .250 OUNCE ON EACH PLANE---.

CHECK-OFF LIST OF THINGS TO BE CONSIDERED & DONE BY ENGINEER MAKING CHANGE

CONSIDER
- [ ] IS CHANGE ESSENTIAL
- [ ] EFFECT ON INVENTORY
- [ ] EFFECT ON PATTERNS & TOOLING
- [ ] EFFECT ON ASSEMBLY
- [ ] EFFECT ON SERVICE

REQ. NOT REQ.
- [ ] [ ] CHANGE ASSEMBLY DRAWINGS - NOS. ______
- [ ] [ ] CHANGE MATERIAL LISTS - NOS. ______
- [ ] [ ] ADVISE PRICING DEPT. - CHECK SQUARE ABOVE IF REQ'D
- [ ] [ ] PLACE NOTE IN STANDING DIRECTIVES BOOK FOR FUTURE ORDERS

OBTAIN FROM PLANNING DEPT.
QTY. ON HAND-ROUGH STOCK ______ QTY. ON HAND-FIN. STOCK ______ QTY. ON ORDER ______

CHANGE REQUESTED BY:
- [ ] PRODUCTION
- [x] ENGINEERING
- [ ] OTHER ______

NATURE OF CHANGE
- [x] MATERIAL
- [x] DIMENSION
- [ ] PATTERN
- [ ] PURCHASE PART
- [ ] OTHER ______

REASON FOR CHANGE
- [ ] CORRECTION OF ERROR
- [x] CLARIFICATION
- [ ] REDUCE MANUFACTURING COST
- [x] TO IMPROVE FUNCTION
- [ ] OTHER ______

EFFECT ON STOCK ON HAND
- [x] NONE IN STOCK
- [ ] USE OUT
- [ ] REWORK
- [ ] SCRAP
- [ ] REWORK AT ASSEMBLY
- [ ] OBS. REPLACEMENT PART ONLY
- [ ] OTHER-EXPLAIN ______

LEASED MACHINERY PARTS

IN SHOP
- [ ] USE OUT
- [ ] REWORK
- [ ] SCRAP
- [ ] OTHER-EXPL ______

IN FIELD
- [x] USE OUT
- [ ] REWORK
- [ ] SCRAP
- [ ] OTHER-EXPLAIN ______

MAKE CHANGE ON

SO# ______

AUTH.# ______

- [x] FUTURE PARTS
- [ ] PARTS IN PROCESS
- [ ] NONE IN STOCK, SHOP ADVISED & ALREADY CHANGING PARTS IN PROCESS

DATE ______
ACTION ON STOCK ______
F.O. ______
ORDER CHANGED ______
P.N. CHANGE ______
OP SHEET CHANGED ______
REMARKS ______

BY ______

CHANGED BY: Chet Kacian

APPROVED BY: D. Chandler

6-15-64
RAE

FORM CMD 08-625
(REV. 4/62)

Exhibit 4.

ECL-17
M.E. 114a-2

FMC CORPORATION
CANNING MACHINERY DIVISION

ENGINEERING CHANGE NOTICE.

DATE: MAY 18 1964

Copies To:
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- [x] PLANNING (OZALID COPY)
- [ ] PATTERN SHOP (OZALID COPY)
- [ ] COST DEPT. (OZALID COPY)
- [ ] OTHER

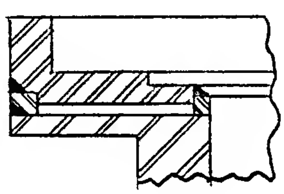
SHT. 3 OF 3

DRAWING NUMBER	PIECE NAME:	PART NUMBER
7380.688089	SCANNING HEAD	7380.688089
SUPERSEDED BY	MACHINE NAME: ROTO SCAN	SUPERSEDED BY

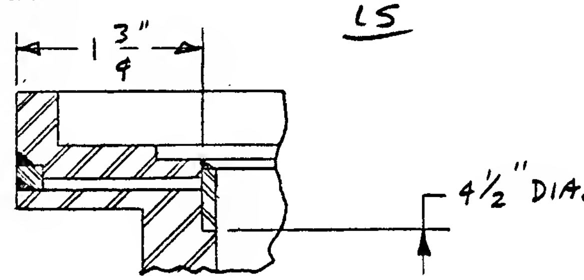
CHG. NO. V

DESCRIPTION OF CHANGE

WAS:



IS



CHECK-OFF LIST OF THINGS TO BE CONSIDERED & DONE BY ENGINEER MAKING CHANGE

CONSIDER
- [ ] IS CHANGE ESSENTIAL
- [ ] EFFECT ON INVENTORY
- [ ] EFFECT ON PATTERNS&TOOLING
- [ ] EFFECT ON ASSEMBLY
- [ ] EFFECT ON SERVICE

REQ.	NOT REQ.	
[ ]	[ ]	CHANGE ASSEMBLY DRAWINGS - NOS.
[x]	[ ]	CHANGE MATERIAL LISTS - NOS.
[ ]	[ ]	ADVISE PRICING DEPT. - CHECK SQUARE ABOVE IF REQ'D
[ ]	[ ]	PLACE NOTE IN STANDING DIRECTIVES BOOK FOR FUTURE ORDERS

OBTAIN FROM PLANNING DEPT.
QTY. ON HAND-ROUGH STOCK ____ QTY. ON HAND-FIN. STOCK ____ QTY. ON ORDER ____

CHANGE REQUESTED BY:
- [ ] PRODUCTION
- [x] ENGINEERING
- [ ] OTHER ____

NATURE OF CHANGE
- [x] MATERIAL
- [x] DIMENSION
- [ ] PATTERN
- [ ] PURCHASE PART
- [ ] OTHER ____

REASON FOR CHANGE
- [ ] CORRECTION OF ERROR
- [x] CLARIFICATION
- [ ] REDUCE MANUFACTURING COST
- [x] TO IMPROVE FUNCTION
- [ ] OTHER ____

EFFECT ON STOCK ON HAND
- [x] NONE IN STOCK
- [ ] USE OUT
- [ ] REWORK
- [ ] SCRAP
- [ ] REWORK AT ASSEMBLY
- [ ] OBS. REPLACEMENT PART ONLY
- [ ] OTHER-EXPLAIN ____

LEASED MACHINERY PARTS

IN SHOP
- [ ] USE OUT
- [ ] REWORK
- [ ] SCRAP
- [ ] OTHER-EXPL ____

IN FIELD
- [x] USE OUT
- [ ] REWORK
- [ ] SCRAP
- [ ] OTHER-EXPLAIN ____

DATE ____
ACTION ON STOCK ____
F.O. ____
ORDER CHANGED ____
P.N. CHANGE ____
OP SHEET CHANGED ____
REMARKS ____

BY ____

MAKE CHANGE ON
SO# ____
AUTH.# ____

- [x] FUTURE PARTS
- [ ] PARTS IN PROCESS
- [ ] NONE IN STOCK, SHOP ADVISED & ALREADY CHANGING PARTS IN PROCESS

CHANGED BY: Chet Kacian

APPROVED BY: D. Sheridan

6-15-64
RDE

FORM CMD 08-625
(REV. 4/62)

Exhibit 4.

ECL-17
M.E. 114a-2

FMC CORPORATION
CANNING MACHINERY DIVISION

ENGINEERING CHANGE NOTICE.

DATE: May 18 1964

Copies To:
- [X] ENGINEERING (ORIGINAL)
- [X] PLANNING (OZALID COPY)
- [ ] PATTERN SHOP (OZALID COPY)
- [ ] COST DEPT. (OZALID COPY)
- [ ] OTHER

SHT. 2 OF 3

DRAWING NUMBER	PIECE NAME:	PART NUMBER
7380.688089	Scanning Head	7380.688089
SUPERSEDED BY	MACHINE NAME: Roto Scan	SUPERSEDED BY

CHG. NO.	DESCRIPTION OF CHANGE
V	NOTE M WAS: CORRECTION DIA. #1 - 3/4" DRILL x 7/8" DEEP MAX. FOR CORRECTION. IS: CORRECTION DIA #1 - DRILL AS REQ'D. NOTE N WAS: CORRECTION DIA #2 - 5/8" DRILL x 1" DEEP MAX FOR CORRECTION. IS: CORRECTION DIA. #2, DRILL AS REQ'D.

CHECK-OFF LIST OF THINGS TO BE CONSIDERED & DONE BY ENGINEER MAKING CHANGE

CONSIDER
- [ ] IS CHANGE ESSENTIAL
- [ ] EFFECT ON INVENTORY
- [ ] EFFECT ON PATTERNS&TOOLING
- [ ] EFFECT ON ASSEMBLY
- [ ] EFFECT ON SERVICE

REQ. NOT REQ.
- [ ] [ ] CHANGE ASSEMBLY DRAWINGS - NOS.
- [✓] [ ] CHANGE MATERIAL LISTS - NOS. 688089
- [ ] [ ] ADVISE PRICING DEPT. - CHECK SQUARE ABOVE IF REQ'D
- [ ] [ ] PLACE NOTE IN STANDING DIRECTIVES BOOK FOR FUTURE ORDERS

OBTAIN FROM PLANNING DEPT.
QTY. ON HAND-ROUGH STOCK ______ QTY. ON HAND-FIN. STOCK ______ QTY. ON ORDER ______

CHANGE REQUESTED BY:
- [ ] PRODUCTION
- [✓] ENGINEERING
- [ ] OTHER ______

NATURE OF CHANGE
- [✓] MATERIAL
- [✓] DIMENSION
- [ ] PATTERN
- [ ] PURCHASE PART
- [ ] OTHER ______

REASON FOR CHANGE
- [ ] CORRECTION OF ERROR
- [✓] CLARIFICATION
- [ ] REDUCE MANUFACTURING COST
- [✓] TO IMPROVE FUNCTION
- [ ] OTHER ______

EFFECT ON STOCK ON HAND
- [✓] NONE IN STOCK
- [ ] USE OUT
- [ ] REWORK
- [ ] SCRAP
- [ ] REWORK AT ASSEMBLY
- [ ] OBS. REPLACEMENT PART ONLY
- [ ] OTHER-EXPLAIN ______

LEASED MACHINERY PARTS

IN SHOP
- [ ] USE OUT
- [ ] REWORK
- [ ] SCRAP
- [ ] OTHER-EXPL ______

IN FIELD
- [✓] USE OUT
- [ ] REWORK
- [ ] SCRAP
- [ ] OTHER-EXPLAIN ______

MAKE CHANGE ON
SO# ______
AUTH.# ______

- [✓] FUTURE PARTS
- [ ] PARTS IN PROCESS
- [ ] NONE IN STOCK, SHOP ADVISED & ALREADY CHANGING PARTS IN PROCESS

DATE ______
ACTION ON STOCK ______
F.O. ______
ORDER CHANGED ______
P.N. CHANGE ______
OP SHEET CHANGED ______
REMARKS ______
BY ______

CHANGED BY: Chet Kacian

APPROVED BY: D. [illegible signature]

6-15-64 RAE

FORM CMD 08-625
(REV. 4/62)

Exhibit 4.

ENGINEERING REQUISITION

FMC CORPORATION

C. M. DIVISION

SPECIFICATION NO. ______ ARTICLE SCANNING HEAD - WELDMENT

SUBASSEMBLY NO. 7380.688089 (5) SIZE ______ QTY ______

DATE 8/12/63 - 12/3/63

WRITTEN BY LHM DESCRIPTION ROTOSCAN

SPECIFICATIONS 1 IN 7380.688090 DRAWING ______

FACTORY ORDER ______

SALES ORDER ______

SHEET 1 TOTAL OF 1.

DATE ISSUED ______

DATE WANTED M

	NAME OF	MATERIAL		PIECE	QUANTITY				PLANNING DEPT. TO ORDER		DETAILED COST				
					REQUIRED		AVAILABLE							AMOUNT	
	PATTERN OR PART	SPEC.	DRAWING	NUMBER	FOR ONE	FOR	ROUGH	FINISH	QTY.	ORDER	LABOR	BURDEN	MATERIAL	ROUGH STOCK	FINISHED STOCK
A	Tube-Seamless-H.R.	1010/20 AISI			1										
B	7 1/2"OD x 3/8"Wall x	17 1/2"Lg.													
C	Tube-Seamless	M.S.	1		1										
D	5 1/4"OD x 1 1/8"Wall	x 7 3/8"Lg.													
E	Tube-Seamless	M.S.			1										
F	4 1/4"OD x 1 1/4"Wall	x 11 1/4" Lg.													
G	Tube-Seamless	M.S.			1										
H	2 7/8"OD x 2 1/4"ID x	4 3/8"Lg.													
J	Plate	M.S.	1 1/8x6 7/8"OD Fin.		1										
K	Plate	M.S.	1 5/8"x6 3/4"OD Fin.		1										
L	Plate	M.S.	1 1/4" x 7 3/8"OD Fin.		1										
M	Tubing	C-1010 1020			1										
N	3 3/4"OD x 5/32"Wall x	2 1/4"	Lg.												
P	Counterweight	Flat Stl.	1"x1 3/4" x 2"Lg.		1										
Q															
R															
S															
T															

FORM 117 (REV. 12/52)

(4)